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ONE-DIMENSIONAL MODEL OF AN INTUMESCENT ABLATOR

by

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Ocean Engineer/Master of Science Thesis
Massachusetts Institute of Technology

The Charles Stark Draper Laboratory, Inc.
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SUBMITTED TO THE DEPARTMENT OF OCEAN ENGINEERING
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in Mechanical Engineering

ABSTRACT

This thesis demonstrates that the one-dimensional charring ablation program, STAB II, can be modified to model the thermal response of an intumescent ablator which is exposed to a transient, low heat flux environment. The inputted conductivity values of the intumescent are the primary means of adjusting the program to account for the surface expansion experienced by intumescent ablators. Testing was performed on several important input parameters to determine their ability to affect the model's predictions. The results of these tests are included and the frequency factor and activation energy of the ablator were determined to be very significant in affecting the model. The computer model was adjusted by altering key input parameters until the model was able to predict the thermal response of one specific intumescent, Firex 2373. In performing the model adjustments, the computer predictions were compared to experimental data. Finally, a discussion is included concerning the naval applications of intumescent coatings which are used in insulating areas of ships from the heat generated by shipboard fires and launched missiles.

Thesis Supervisor: Dr. Warren M. Rohsenhow
Title: Professor of Mechanical Engineering

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A special thanks is extended to Dr. Donald M. Curry of the NASA Manned Spacecraft Center who wrote the computer program used in this thesis. His early encouragement and continued help with the program significantly contributed to the success of this thesis.

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Publication of this thesis does not constitute approval by The Charles Stark Draper Laboratory, Inc. of the findings and conclusions contained herein. It is published solely for the exchange and stimulation of ideas.

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A	collision frequency, frequency factor
CA	frequency factor (computer variable)
c_p	specific heat
E	activation energy
F	exterior view factor
F_e	view factor and emissivity product for radiant heat transfer into the cabin
H_e	film coefficient to interior cabin environment
H_v	heat of degradation
HV	heat of degradation (computer variable)
k	thermal conductivity
K	reaction rate constant
$\dot{m}$	mass flow rate
n	order of reaction
NP	number of nodes in ablation material (computer variable)
$\dot{q}_{in}$	net heat rate into front surface
$\dot{q}_{rad}$	radiation heat flux

R	gas constant
$\dot{S}$	surface recession rate
SN	order of Arrhenius equation (computer variable)
T	temperature of node at beginning of time step
T_e	temperature of interior cabin environment
T'	temperature of node at end of time step
T_∞	radiation heat sink temperature
x	distance from surface to any point
XB	activation energy (computer variable)
Δx	thickness of node
$\Delta\theta$	time step ($\theta' - \theta$)
ε	emissivity of material
θ	initial time
θ'	final time
ρ	density
σ	Stefan-Boltzmann constant
τ	time

Subscripts:

c	charred state
g	pyrolysis gas
i	node number
j	backup material number
v	virgin state

Note: A complete listing of computer input variables is contained in Appendix B.

PREFACE

This thesis is the result of an investigation conducted at The Charles Stark Draper Laboratory, Inc. by my colleagues, LCDR James M. Leary, Lt. Joseph P. Marques, and myself. The primary focus of our re-research was to learn the uses and properties of ablative materials with the ultimate objective of recommending alternate ablative materials to be used in insulating an inertial measurement unit (IMU) from a transient, low heat flux environment. Our work was initiated by the possibility of placing the IMU in a new thermal operating environment. We began by studying several ablative materials and then procuring those for testing which promised to be the most effective in protecting the IMU.

To reinforce the testing phase, I chose to model the ablation process through a one-dimensional computer program. It was hoped that the computer results could be directly compared to the test results. My contribution would be adjusting the computer program to more accurately model the materials in question. Finally, the computer program could serve as a design tool in determining the ablative effectiveness of any new ablative materials by merely inputting simple thermophysical properties of the material. As my work progressed, it became clear that time would permit the adjustment of the computer model for only one material. Since the material being presently used is Firex 2373, and since early test results indicated that Firex was the best material for our application, I decided to concentrate on modeling this material with the computer program. In order to better understand the results of this thesis, I recommend reading the theses of my colleagues.

CHAPTER 1

INTRODUCTION

1.1 Ablation

1.1.1 General

Ablation is a complex phenomena involving a material's ability to adsorb tremendous amounts of incident heat while sacrificing its surface mass. As an ablative material is exposed to heat, the heat flow initially penetrates at a low rate because of the low thermal conductivity of the ablator. This causes a rapid temperature rise on the surface with a subsequent phase change and thermal degradation of the material into pyrolysis gases and porous carbon char. During the phase change of the virgin plastic composite into lower molecular constituents and char, an enormous amount of heat is absorbed. Thus, the process is insulative to the remaining substrates. In addition to the heat absorbed in creating the chemical decomposition of the material, the pyrolysis gases themselves absorb incident heat as they percolate through the surface. To restate the ablation phenomenon another way is to explain that ablation is the thermal decomposition of high polymers into low-molecular weight gaseous products and a porous char.[1]

Ablative materials are a product of man's exploration of space. Although these materials are still widely used in reentry applications, they are beginning to find use in less severe thermal environments. There are many different types of ablative materials ranging from the silica, subliming-reradiative tiles used on the space shuttle to the intumescent ablators used in fire-retardant paints. Although each type

of ablator generally dissipates incident heat through chemical decomposition, the mechanism in which each type performs their protective roles are quite different.

The most common type of ablator is the charring ablator. A physical model of a charring ablator is seen in Figure 1.1. Charring ablators have been used frequently as heat shield materials on space vehicles where the large amount of heat they can adsorb through their chemical degradation makes them ideally suited for the high heat loads of reentry. The pyrolysis gases generated by the chemical decomposition in the reaction zone also absorb incident heat as they percolate towards the surface. The char formed at the surface serves to insulate the substrate from incoming radiation as well as to reradiate a significant amount of heat back out of the material. Charring ablators appear to be most effective in situations where the integrated heat flux is over 1000 Btu/ ft^2.(2) The charring ablator is particularly noteworthy to this thesis because it is a one-dimensional charring ablation computer program which is used to model an intumescent ablator.

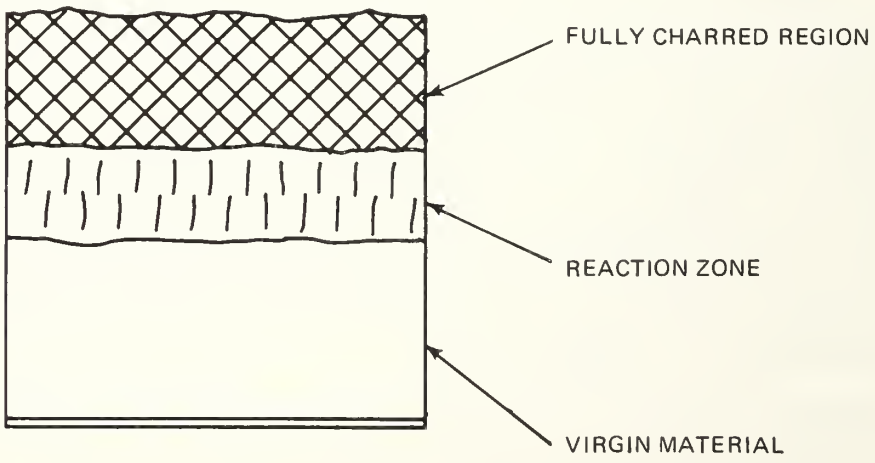


Figure 1.1. Physical mode of a charring ablative.

1.1.2 Intumescent Ablator

An intumescent ablator is quite similar to a char forming ablator except that as the ablator begins to degrade, it expands or swells thus increasing its thickness and drastically reducing its effective conductivity. So in addition to a reaction zone, an intumescent ablator has a zone of material which has swelled called the intumescent zone as seen in Figure 1.2. Firex 2373 is an intumescent ablator and Figure 1.3a and b show the swelling Firex 2373 experiences when it is exposed to heat and

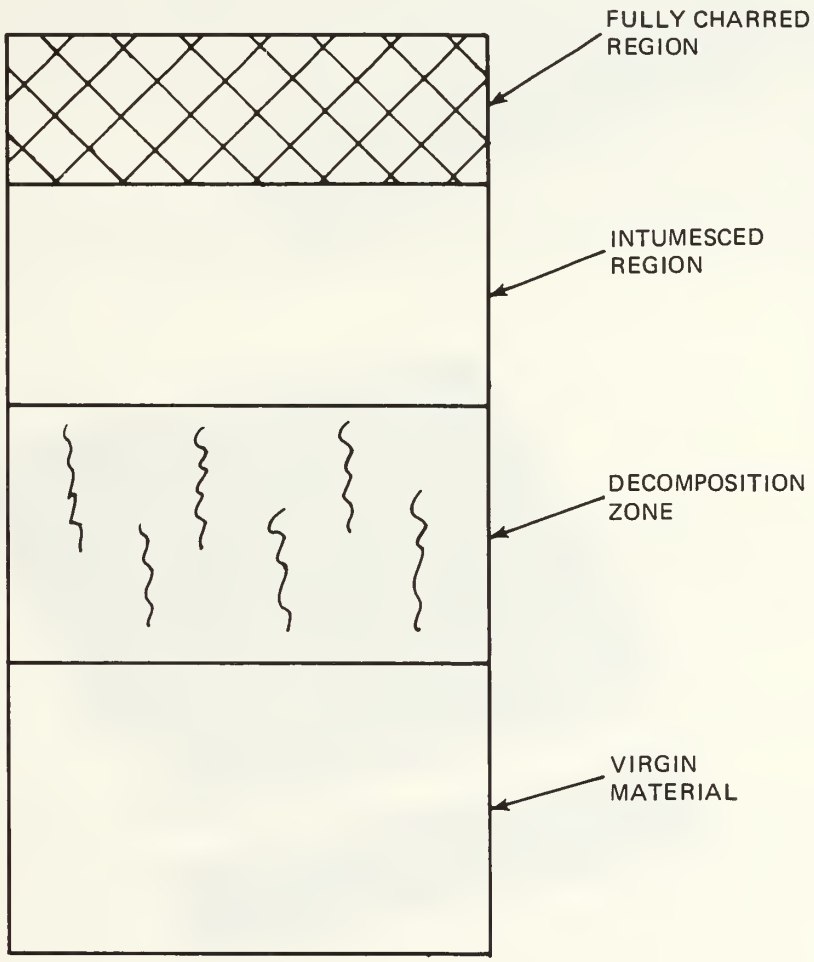
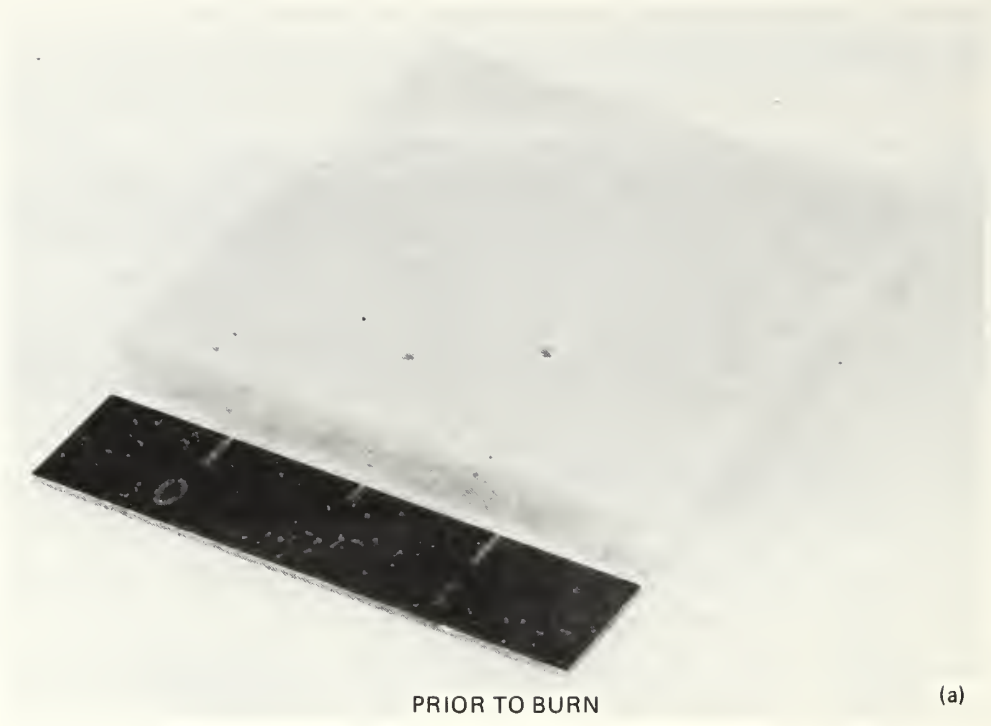
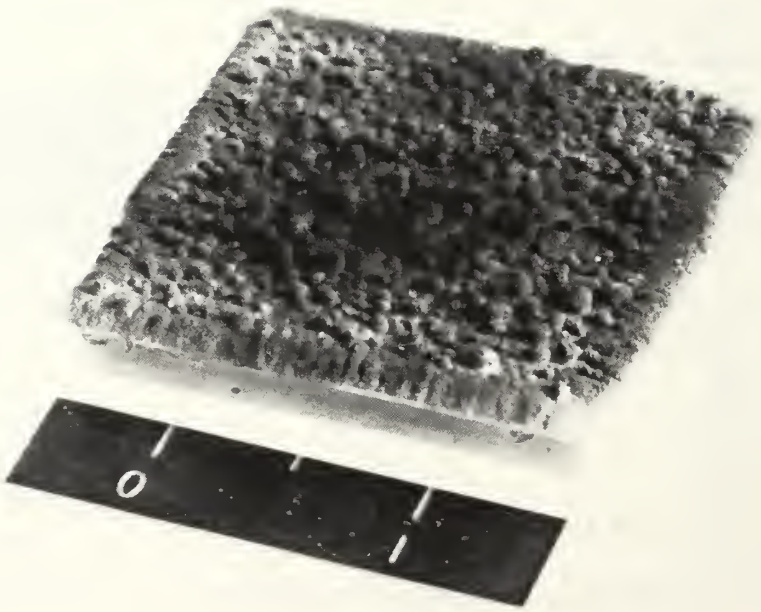


Figure 1.2. Physical model of an intumescent ablator.



PRIOR TO BURN (a)



AFTER BURN (b)

Figure 1.3. Firex 2373.

undergoes degradation. As mentioned, the effective conductivity of the intumesced material decreases significantly and thus, the intumesced region forms an excellent insulation for the material below it. This drastic conductivity change is the primary mechanism employed by an intumescent ablator in protecting the substrate from heat. Figure 1.4 shows the manufacturer's conductivity model for the intumescent ablator, Flexfram. The manufacturer is Fiber Materials, Inc.

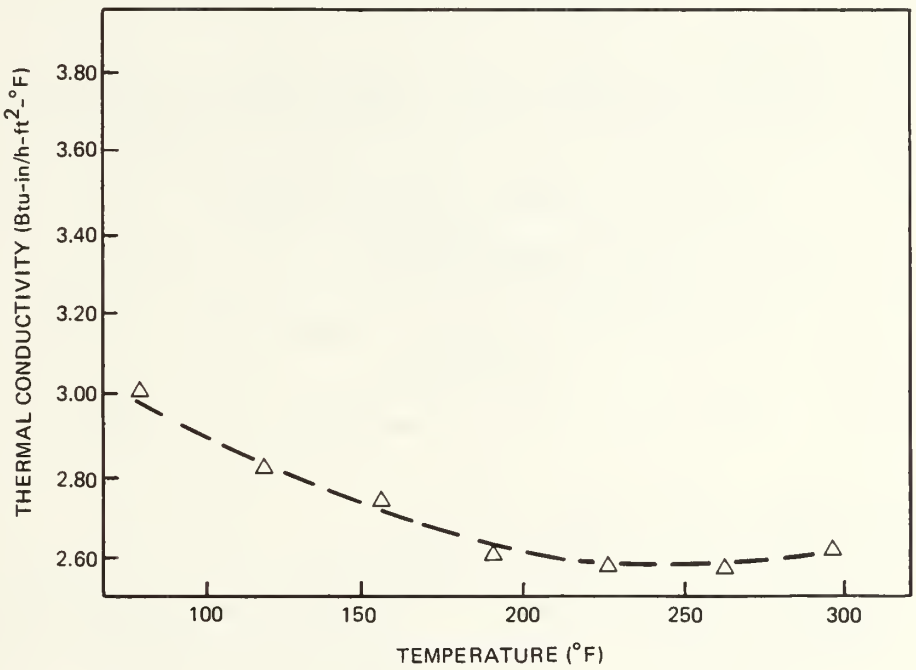


Figure 1.4. Manufacturer's thermal conductivity model for Flexfram.

Although an intumescent ablator forms a char layer, the char formed is significantly less than the char formed on a charring ablator. The char on an intumescent ablator has very little reradiative capability and merely serves to cut off the oxygen supply to the substrates. Intumescent ablators are best suited for applications in low to moderate heat flux environments. Intumescents are typically used when the integrated heat flux is less than 1000 Btu/ft^2 as was the case encountered in our

research group's application. For more information on charring and intumescent ablators see the work of my colleague, LCDR James Leary, whose thesis, Reference (2), gives a detailed description of all types of ablative materials.

1.1.3 Firex 2373

The following table of properties for Firex 2373 is included for reference purposes. Note these values have been supplied by the manufacturer, Pfizer Inc.

Table 1.1. Thermophysical properties for Firex 2373.

k	37.50×10^{6} Btu/s-ft-°F
C_p	0.47 Btu/lb-°F
ρ	77.76 lb/ft^3
α	2.03×10^{6} ft^2/s

1.2 Selection of the Computer Program

Unfortunately a time restraint prevented the extensive study of all the available ablation programs. Nevertheless, a small survey was conducted on several of the existing programs and a selection was made. The following ablation programs were readily available through the literature and considered for use in modeling Firex 2373:

(1) CHAP (Charring Ablation Computer Code) - Aerotherm Corp., NASA/Langley[3,4]

(2) WOTA (Working Tool Ablation) - Lockheed/Huntsville[5]

(3) ABLATIN1, ABLATIN2 - LSU/NASA[6]

(4) STABII (Standard Ablation Program II) - NASA/Houston[7,8]

The Lockheed/Huntsville program was not seriously considered because this program is not intended to be a separate entity but a subprogram in a larger program. The preliminary documentation of the Aerotherm program indicated that too many unknown material properties were needed as inputs so it was dropped from consideration. This author really liked the LSU program because of its detail in the chemical degradation of the ablative material, but this same degree of detail made the program too complicated to be easily adapted to model Firex. This program was really written from the viewpoint of a chemical engineer.

This left the NASA/Houston program, STAB II, for which excellent documentation was available. The program incorporated all the major ablative calculations included in the other programs but its author, Dr. Curry, strove to make the program simple and flexible. It seemed ideal for our applications. A call to Dr. Curry and receipt of the user's manual,[8] further confirmed that STAB II could meet our research needs. STAB II was thus chosen to model Firex 2373. Dr. Curry's initial encouragement in using his program to model an intumescent ablator was certainly another major reason for selecting his program. There are many other ablation programs in use throughout the country. In fact, Dr. Curry indicated that his office maintained several other ablative programs which are more sophisticated than STAB II but that in his experience the extra sophistication did not really make the programs more accurate in predicting the thermal response of a charring ablator.

1.3 The Experiment

The experimental work of Lt. Marques would serve two purposes. First, the results of his work would provide a ranking of all candidate materials tested in order of their ablative effectiveness. Secondly, and most importantly for this thesis, Lt. Marques's testing on Firex 2373 would provide the thermal response data of Firex to be used in the computer matching of the STAB II program.

The testing performed to support this thesis consisted of exposing the 1-inch diameter circular face of a 2-inch slug of Firex to a constant heat flux of 10 Btu/ft^2-s for a period of 200 seconds. A holder was designed to ensure the slug only experienced one-dimensional heat flow and the slug was instrumented with thermocouples at the following distance from the exposed surface: 0.0625, 0.125, 0.25, and 1.0 inch. See Figure 1.5 for a picture of a standard slug. During each run, continuous thermocouple temperatures were recorded until each thermocouple peaked in temperature. The slugs were burned for 200 seconds because, in the original problem formulation at The Charles Stark Draper Laboratory, a burn of 200 seconds was anticipated in a future design. In matching the experimental results with the computer model, the decision was made to match the results at the 0.25-inch thermocouple because the thickness of the Firex currently used on the IMU is approximately 0.20 inch.

One of the problems encountered by Lt. Marques in preparing the slugs was accurately placing all the thermocouples at their prescribed depth and later each slug was x-rayed to ensure the 0.25-inch thermocouple was, in fact, at 0.25 inch from the surface. As will be seen in n the next chapter, the computer program allows for an exact placement of a thermocouple anywhere within the ablative material.

1.4 "Effective" Conductivity

The major objective of this thesis was to use a proven charring ablation program, STAB II, to model the thermal response of an intumescent ablator. The particular intumescent to be modeled would be, as previously mentioned, Firex 2373. The success of using a charring ablation program to model Firex would depend primarily on the ability to correctly model the conductivity of Firex over the temperature range it experiences in ablation. Because the STAB II program will only account for surface recession as experienced in charring ablators and not for surface expansion or material swelling as experienced by intumescent

Figure 1.5. Standard slug.

ablators, the conductivity model had to be adjusted to allow for the swelling effect. Thus, the conductivity values finally selected to represent the material are really "effective" conductivity values.

CHAPTER 2

STANDARD ABLATION PROGRAM

2.1 Description of STAB II

The STAB II or Standard Ablation program has been evolving over the years since its original inception in 1965 by Dr. Donald M. Curry. The original program as described in Reference (7) has remained largely unchanged. In comparing the current modified version of the program as described in Reference (8) with Reference (7), one quickly discovers that most of the changes to the original program have been of an esoteric nature. An easier input format has been incorporated, more complete tabular output is available, and several complex plotting routines have been added; but still the basic framework for the ablative calculations are just as they were in the 1965 version.

There have been, however, a few innovations incorporated into the original program which were made to include state-of-the-art understanding of the ablative process. Perhaps the most significant of the new innovations, is the use of an Arrhenius equation to model the generation of the pyrolysis gases which are produced as the material ablates. The significance of the Arrhenius equation will be discussed later in this chapter.

STAB II, originally written for the Apollo space program, is still an actively used model at NASA.[10] The very fact that Dr. Curry's program has stood the test of time is particularly noteworthy. This author considers himself extremely fortunate to have had the program available

for his thesis work and also to have had the opportunity to speak with Dr. Curry on a regular basis during the course of this work.

Quite simply, STAB II is an analytical model for predicting the transient response of a one-dimensional, charring ablation thermal protection system. This program was originally designed for protection systems subject to hyperthermal environments. But as proved by this thesis, the generalities incorporated into the program by Dr. Curry have made the model highly suitable for predicting thermal responses in heat flux regimes significantly lower than those encountered during atmospheric reentry.

The object of Dr. Curry's efforts was to write a digital computer program to analyze a charring ablation protection system which would have the following general requirements:[7]

(1) Stability of the equations for all applications.

(2) Machine running time short enough to make use of the program economically feasible (a minimum of turnaround time per problem).

(3) A minimum input per problem.

(4) A wide variety of boundary conditions for application to both trajectory data and ground or flight test data analysis.

STAB II was originally written in FORTRAN IV by Dr. Curry and then TRW, Inc. adapted it to FORTRAN V, which is an enhanced version of FORTRAN IV on the UNIVAC 1108 computer. As part of the preparation for this thesis, the author has adapted the program to the newest FORTRAN, FORTRAN 77 or VS FORTRAN. Fortunately, the changes from FORTRAN V to VS FORTRAN proved to be relatively minor in nature.

The program considers one ablating material and up to 12 different backup materials which can be separated with or without air gaps. Pure conduction or radiation and/or convection between backup materials is

allowed. The ablation material may be divided into a maximum of 50 nodes and each of these nodes may be further subdivided into 20 subnodes to calculate the pyrolysis gas generation. The only requirement is that the product of the number of nodes and the number of subnodes must not be greater than 500. Each backup material may be subdivided into a maximum of 10 nodes. The thermal properties of the ablative materials are input in tabular form and they can be temperature-dependent. The ablation material is also dependent upon its state, that is, fully charred, or partially charred.

Several options are available for the surface boundary condition. These options which greatly enhance the versatility of the program are:[8]

(1) Cold-wall convective and radiative heat flux tables as a function of time. These components are specified separately, since mass transfer at the surface blocks part of the convective heating but, in general, has no effect on the radiative heating. In the User's Manual this is called the heating rate driver option.

(2) Surface temperature as a function of time. In the User's Manual this is called the thermocouple driver option.

(3) Surface recession as a function of temperature or time. Surface recession as a function of temperature and pressure is also available.

Heat loss to the interior environment from the last node of the backup structure can be specified by two methods:[8]

(1) Conduction into the node and radiation and/or convection loss to the interior environment.

(2) Conduction into the node and adiabatic wall.

An implicit solution is used in the numerical formulation of the equations describing the response of a charring ablator in STAB II. It

is well known that numerical solutions of partial differential equations are subject to several different types of errors.[7] The first of these errors is the truncation error, due to the use of a finite subdivision. This error may be reduced by simply choosing a smaller subdivision, Δx. The exact values are approached more and more closely as Δx decreases. The second kind of error is the numerical, or round off error. It is the way in which this numerical error grows or decays with time that determines the stability of the difference equations.

In his original paper, Reference (7), Dr. Curry includes the following example to demonstrate the differences between an explicit or an implicit finite difference formulation. Consider a nonablating homogeneous solid. The one-dimensional Fourier conduction equation, neglecting any heat generation terms, is

$$\frac{\partial}{\partial x}\left(k\,\frac{\partial T}{\partial x}\right) = \rho c_p \frac{\partial T}{\partial \theta} \tag{2-1}$$

The finite difference form of Eq. (2-1) written in the conventional forward time step or explicit form for the i^{th} node is

$$\frac{(T_{i-1} - T_i)}{\frac{\Delta x}{2k_{i-1}} + \frac{\Delta x}{2k_i}} - \frac{(T_i - T_{i+1})}{\frac{\Delta x}{2k_i} + \frac{\Delta x}{2k_{i+1}}} = \rho c_p \frac{\Delta x (T_i' - T_i)}{\Delta \theta} \tag{2-2}$$

where the prime superscript denotes the values at the end of the time step or

$$\Delta\theta = \theta' - \theta \tag{2-3}$$

For explicit conduction solutions, the following stability criterion has been established[7,11]

$$\frac{\rho c_p}{k} \frac{(\Delta x)^2}{\Delta\theta} \geq 2 \qquad (2\text{-}4)$$

which places an upper limit on the time step, $\Delta\theta$, for a fixed truncation error. This criterion can require a prohibitive amount of machine time.[7]

Liebmann, in Reference (12), advocated a solution of the equation which does not require this stability criterion. The finite difference equations are written in a backward time step form which affords an implicit solution.

The implicit (backward time step) difference form of Eq. (2-1) for the i^{th} node is

$$\frac{(T'_{i-1} - T'_i)}{\frac{\Delta x}{2k_{i-1}} + \frac{\Delta x}{2k_i}} - \frac{(T'_i - T'_{i+1})}{\frac{\Delta x}{2k_i} + \frac{\Delta x}{2k_{i+1}}} = \rho c_p \frac{\Delta x (T'_i - T_i)}{\Delta\theta} \qquad (2\text{-}5)$$

Eq. (2-5) uses the temperature differences at the end of the finite time interval instead of at the beginning, as in the explicit method of Eq. (2-2). The only known temperature in Eq. (2-5) is T_i, but there are corresponding equations for each node in the system, and all are solved simultaneously to yield the temperature at each node.

Collecting all unknown temperatures on the left side of the equation and the known temperature on the right side, Eq. (2-5) becomes

$$\left(\frac{1}{\frac{\Delta x}{2k_{i-1}} + \frac{\Delta x}{2k_i}}\right) T'_{i-1} - \left(\frac{1}{\frac{\Delta x}{2k_{i-1}} + \frac{\Delta x}{2k_i}} + \frac{1}{\frac{\Delta x}{2k_i} + \frac{\Delta x}{2k_{i+1}}} + \frac{\rho_i c_{pi} \Delta x}{\Delta\theta}\right) T'_i + \left(\frac{1}{\frac{\Delta x}{2k_i} + \frac{\Delta x}{2k_{i+1}}}\right) T'_{i+1} = -\left(\frac{\rho_i c_{pi} \Delta x}{\Delta\theta}\right) T_i \qquad (2\text{-}6)$$

Eq. (2-6) is of the form

$$AT'_{i-1} + BT'_i + CT'_{i+1} = D \tag{2-7}$$

In STAB II, such an equation is generated for each node in the system. Specifically, the subroutine COEFF is used to calculate the coefficients, A, B, C, and D, of Eq. (2-7).

Because radiation is an important mode of heat transfer in a charring ablator, a problem is encountered in any equation which contains a radiation term. The radiation heat flux, written in a backward difference form is

$$\dot{q}_{rad} = F\varepsilon\sigma\left(T_i^4 - T_\infty^4\right) \tag{2-8}$$

This term cannot be used in an implicit solution since the unknown temperature is raised to the fourth power.[7] The fourth power unknown can be eliminated by the following linearizations[7]

$$(T_i)^4 = (T_i + \Delta T)^4 = T_i^4\left(1 + \frac{\Delta T}{T_i}\right)^4 \tag{2-9a}$$

$$\Delta T = T'_i - T_i \tag{2-9b}$$

$$Z \equiv \frac{\Delta T}{T_i} \tag{2-9c}$$

Rewriting Eq. (2-9) as

$$(T'_i)^4 = (T_i)^4(1 + Z)^4 \tag{2-10}$$

Now if Z has an absolute value near zero, the following is true

$$(1 + Z)^4 \cong 1 + 4Z \tag{2-11}$$

Substituting Eq. (2-11) into Eq. (2-10)

$$(T_i')^4 \cong (T_i)^4(1 + 4Z) = (T_i)^4\left(1 + 4\frac{\Delta T}{T_i}\right)$$

$$\cong 4T_i^3T_i' - 3T_i^4 \tag{2-12}$$

Eq. (2-12) is a linearized approximation of Eq. (2-9), in which the only unknown temperature is only raised to the first power. The assumption in Eq. (2-12) is that T_i has an absolute value near zero. Dr. Curry has determined that for most ablation problems in which surface temperature is high and radiation losses are significant, the value of $\frac{\Delta T}{T_i}$ can easily be controlled to values of less than ±0.1.[7] Therefore, Eq. (2-8) can be written as

$$\dot{q}_{rad} = F\varepsilon\sigma\left(4T_i^3T_i' - 3T_i^4 - T_\infty^4\right) \tag{2-13}$$

Note in Eq. (2-13), the only unknown term is the temperature, T_i', the temperature at node i at the next time step.

Using the linearized approximation for the radiation terms, the resulting system of implicit difference equations constitutes a tridiagonal matrix of the following form[7]

$$
\begin{aligned}
B_1T_1 + C_1T_2 &= D_1 \\
A_2T_1 + B_2T_2 + C_2T_3 &= D_2 \\
A_3T_2 + B_3T_3 + C_3T_4 &= D_3 \\
\vdots \quad\quad \vdots & \quad\quad \vdots \\
A_NT_{N-1} + B_NT_N &= D_N
\end{aligned}
$$

Gauss' elimination method, discussed in Reference (13) is applied to solve the system of equations. This method yields a fast and accurate solution for matrices containing a dominant diagonal. The solution of this matrix gives the temperature of each node in the system for the next future time step. The entire process is repeated for each time step throughout the run, giving a history of the temperature at each node.

By using this method, residual errors in the temperature computations at the beginning of the time step are distributed throughout the entire system of nodal equations and tend to cancel out rapidly. The principal advantage in using the implicit method is a set of equations that are mathematically stable in time and distance. Therefore, the magnitude of the time step is not limited by a convergence criterion. However, as discovered by this author, care must be taken in selecting the magnitude of the time step in order to minimize truncations errors whenever the second derivative of temperature with respect to time is large. Similarly, to minimize truncation errors in distance, small node dimensions should be used in areas where the second derivatives of temperature with respect to distance are expected to be large.

As noted by Dr. Curry, Reference (7), in the case of a char-forming ablative material where approximately 80 percent of the heat is reradiated, instability can arise in taking large time steps. The temperature of the surface node can start oscillating on successive time steps when a balance between the radiation source and the ablative material has been achieved. Therefore, in ablation problems in which the

surface node loses a large percentage of heat by reradiation, oscillations of the node can be damped out by taking small time steps during conditions of high heat flux and when near radiation equilibrium temperatures.[7] Even though this thesis exercised the program at relatively low heat fluxes (10 Btu/ft^2-s), the problem of surface node oscillation occurred during runs in which the low heat flux was applied for a relatively long time, as in 200 seconds. As recommended by Dr. Curry, this problem was solved at the expense of increased computer time by reducing the time step of the calculations.

2.2 STAB II Methodology

The purpose of this section is to describe how the STAB II program models the ablative process. This will entail an in-depth analysis of the nodal energy balances, both at the surface and interior nodes of the virgin ablative material, as well as at the nodes of the backup materials. Most of the information for this section comes from Chapter 1 of the STAB II User's Manual.[8]

2.2.1 Description of the Physical System

The transient response of a one-dimensional, charring thermal protection system is the result of a complex set of physiochemical processes which are impossible to model exactly. The STAB II computer program is the result of modeling a simplified physical system as shown in Figure 2.1.

The basic ablation mechanism modeled in the program is the pyrolysis of ablative material described by the expression:

$$\text{Virgin material} \rightarrow \text{gas} + \text{char} \qquad (2\text{-}14)$$

This pyrolysis process is assumed to occur in the reaction zone defined by temperature and density limits. In particular, the regions of the

ablative material (which are called the virgin region, the reaction zone region, and the char region) are defined by the following density ratio:

$$THETA_i = \frac{\rho_i - \rho_c}{\rho_v - \rho_c} \qquad (2\text{-}15)$$

where

ρ_c = the density of char material

ρ_v = the density of virgin material

ρ_i = the node density calculated by subroutine ABLATE

A node is in the reacting zone if its THETA value is in the range (0.01, 0.995). For THETA less than or equal to 0.01, the node is in the char zone. Pyrolysis gas generation can not begin until the nodal temperature reaches the temperature of ablation, TABL, (TABL is an input item). Therefore, $THETA_i$ remains 1 until the node temperature is greater than or equal to TABL.

In addition to the basic pyrolysis of the virgin ablator, the following energy transport mechanisms may occur as noted in Figure 2.1[8]

(1) Transport by convection of the pyrolysis gases through the porous char.

(2) Transport by conduction throughout the entire system.

(3) Transport by reactions between the char and pyrolysis gas products such as redeposition of pyrolysis gas products on the char structure (coking) and reactions between char and pyrolysis gas constituents.

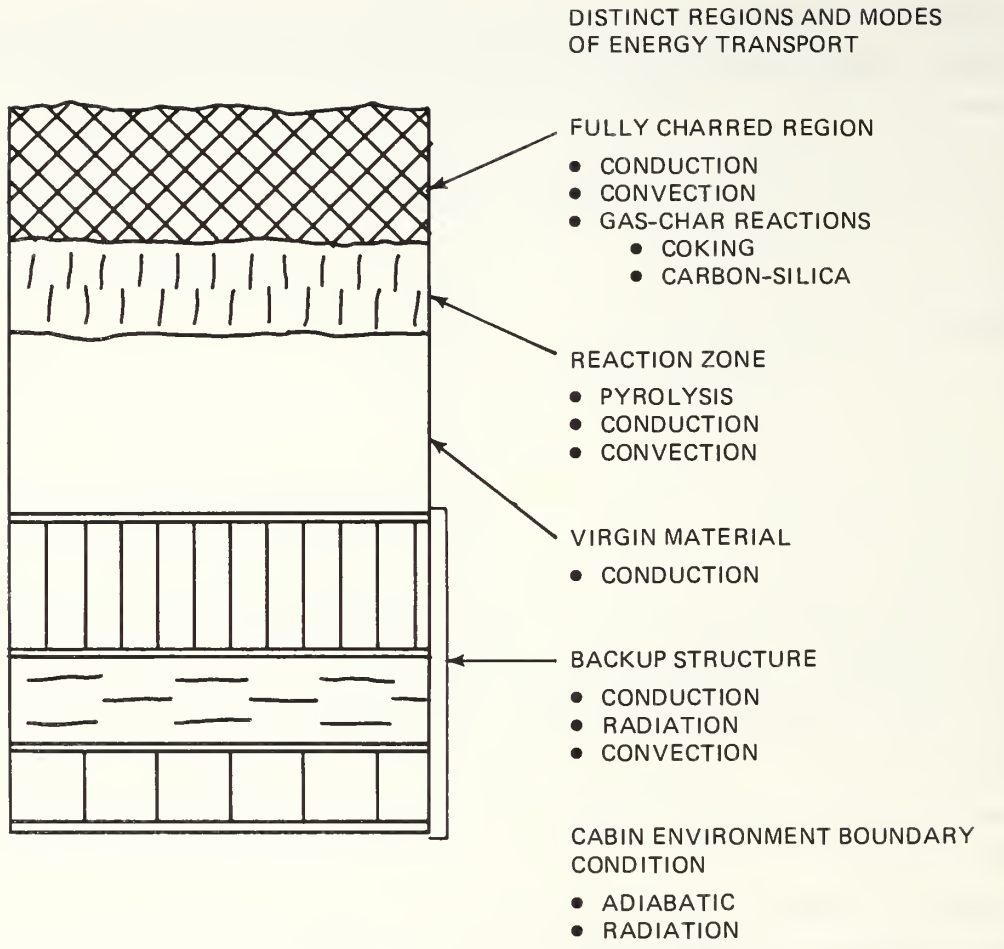


Figure 2.1. Physical model of a charring ablator.

2.2.2 Formulation of the Energy Equation

The calculation of the in-depth response requires the solution of an energy equation of the form[8]

$$\rho c_p \left(\frac{\partial T}{\partial \tau}\right) = \frac{\partial}{\partial x}\left(K \frac{\partial T}{\partial x}\right) + \sum_i \dot{m}_i c_{p_{g_i}} \left(\frac{\partial T}{\partial x}\right) + \sum_j \upsilon_j H_{v_j} \left(\frac{\partial \rho_j}{\partial \tau}\right) + \sum_k Q_k(x) \tag{2-16}$$

where the individual terms represent:

$$\rho c_p \left(\frac{\partial T}{\partial \tau}\right) = \text{rate of energy storage} \qquad (2\text{-}16a)$$

$$\frac{\partial}{\partial x}\left(K \frac{\partial T}{\partial x}\right) = \text{heat conduction} \qquad (2\text{-}16b)$$

$$\sum_i \dot{m}_i c_{p_{g_i}} \left(\frac{\partial T}{\partial x}\right) = \text{heat convected by pyrolysis gases} \qquad (2\text{-}16c)$$

$$\sum_j \upsilon_j H_{v_j} \left(\frac{\partial \rho_j}{\partial \tau}\right) = \text{rate of heat absorption due to thermochemical reaction of the ablative material constituents} \qquad (2\text{-}16d)$$

$$\sum_k Q_k(x) = \text{possible additional modes of heat absorption or liberation not otherwise accounted for} \qquad (2\text{-}16e)$$

The boundary conditions at the ablator surface in the most general form are illustrated in Figure 2.2 and described by the expression[8]

$$Gq_{HW} + q_{radiation} + q_{combustion} - q_{reradiation} - q_{sublimation} = -K \left.\frac{\partial T}{\partial x}\right|_{x=0} \qquad (2\text{-}17)$$

where the terms above represent the following:

$$Gq_{HW} = \text{hot wall convective flux corrected for the effects of mass injection into the boundary layer} \qquad (2\text{-}17a)$$

$$q_{radiation} = \text{incident radiative heat flux} \qquad (2\text{-}17b)$$

$q_{combustion}$ = heat liberated at the surface due to combustion of char constituents with boundary layer gaseous species (2-17c)

$q_{reradiation}$ = heat flux reradiated from surface (2-17d)

$q_{sublimation}$ = energy absorbed due to char sublimation (2-17e)

$$K \frac{\partial T}{\partial x}\bigg|_{x=0} = \text{conduction at ablator surface} \quad (2\text{-}17f)$$

At the ablator/backup structure bondline, the boundary condition is one of strictly conduction

$$-K \frac{\partial T}{\partial x}\bigg|_{x=L} = -K_{bs} \frac{\partial T}{\partial x}\bigg|_{x=L} \quad (2\text{-}18)$$

The boundary condition at the interface between the last backup material and the backside environment can allow for radiation or it can be adiabatic.

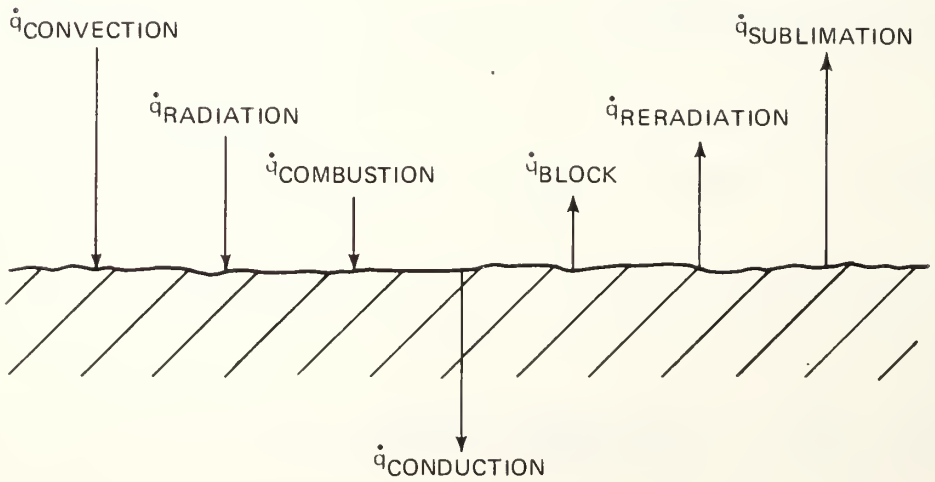


Figure 2.2. Surface energy balance.[8]

2.2.3 STAB II Version of the Energy Equation

Eq. (2-16) represents the general form of the energy equation for describing the charring ablation process. Since the STAB II program is modeling a simplified representation of the complex chemistry by assuming (Eq. (2-14))

$$\text{virgin material} \rightarrow \text{gas} + \text{char}$$

the summation terms of Eq. (2-16) may be represented by equivalent values.[8] Neglecting any additional modes of heat absorption or liberation, the following form of the energy equation is obtained:

$$\rho c_p \left(\frac{\partial T}{\partial \tau}\right) = \frac{\partial}{\partial x}\left(K \frac{\partial T}{\partial x}\right) + \dot{m}_g \bar{c}_{p_g} \left(\frac{\partial T}{\partial x}\right) + \bar{H}_v \left(\frac{\partial \rho}{\partial t}\right) \qquad (2\text{-}19)$$

Many ablative materials, particularly those exposed to a hyperthermal atmospheric entry environment, experience surface recession. To account for surface recession in the energy equation, Dr. Curry has incorporated a moving coordinate system via the Landau transformation. This transformation will not be detailed here because, under the low heat fluxes our group studied, surface recession was never a factor and thus, surface recession was purposely input to be zero during all times and temperatures. The details of this coordinate transformation are contained on page 1-6 of Reference (8). Before proceeding to the nodal difference formulations, it is appropriate to consider some of the expressions involved in the mathematical simulation of the ablation process.

2.2.4 The Use of an Arrhenius Equation

All ablative materials experience a mass loss as they ablate. This mass loss is a result of the chemical degradation of the material constituents which are in the "reaction" zone. As the material undergoes chemical decomposition, pyrolysis gases are produced which percolate out

of the material through the surface, thus removing mass from the ablative system. Incident heat is adsorbed in producing the chemical degradation of the material and also, the pyrolysis gases themselves adsorb incident heat as they percolate through the material. As noted in Reference (6), the pyrolysis gases serve as a major mechanism in removing heat from an ablative material and, therefore, in any ablation simulation it is very important to accurately model the generation of these gases.

The technique used to model the generation of the pyrolysis gases involves examining the mass loss an ablative material experiences over various temperatures when heated by a constant heating rate. A test has been designed for just this purpose and it is called a thermogravimetric analysis or TGA. Very simply, a TGA test of an ablative material involves placing a small sample of the material in a crucible which is on a scale. The sample is then heated from ambient temperature to a predetermined maximum temperature (i.e., 2000°F) at a constant temperature-rise rate. During the heating cycle the thermobalance continuously records mass changes of the sample.

The thermogravimetric data for a typical charring ablation material is seen in Figure 2.3. This S-shaped curve is typical for most ablative materials. The middle part of the curve with the downward slope represents the region over which chemical degradation is occurring and pyrolysis gases are being produced. Some materials experience chemical degradation and mass loss over multiple temperature regions and their TGA curves reflect this.

Early researchers trying to model the ablation process encountered many difficulties in analytically representing the pyrolysis gas generation and associated mass loss phenomenon. Finally, many investigators discovered that this mass loss could be accurately modeled by the use of an Arrhenius equation. This reporter has discovered that, in fact, almost all current ablation models use an Arrhenius-type equation to model the mass loss or rather the gas generation which takes place in ablation.

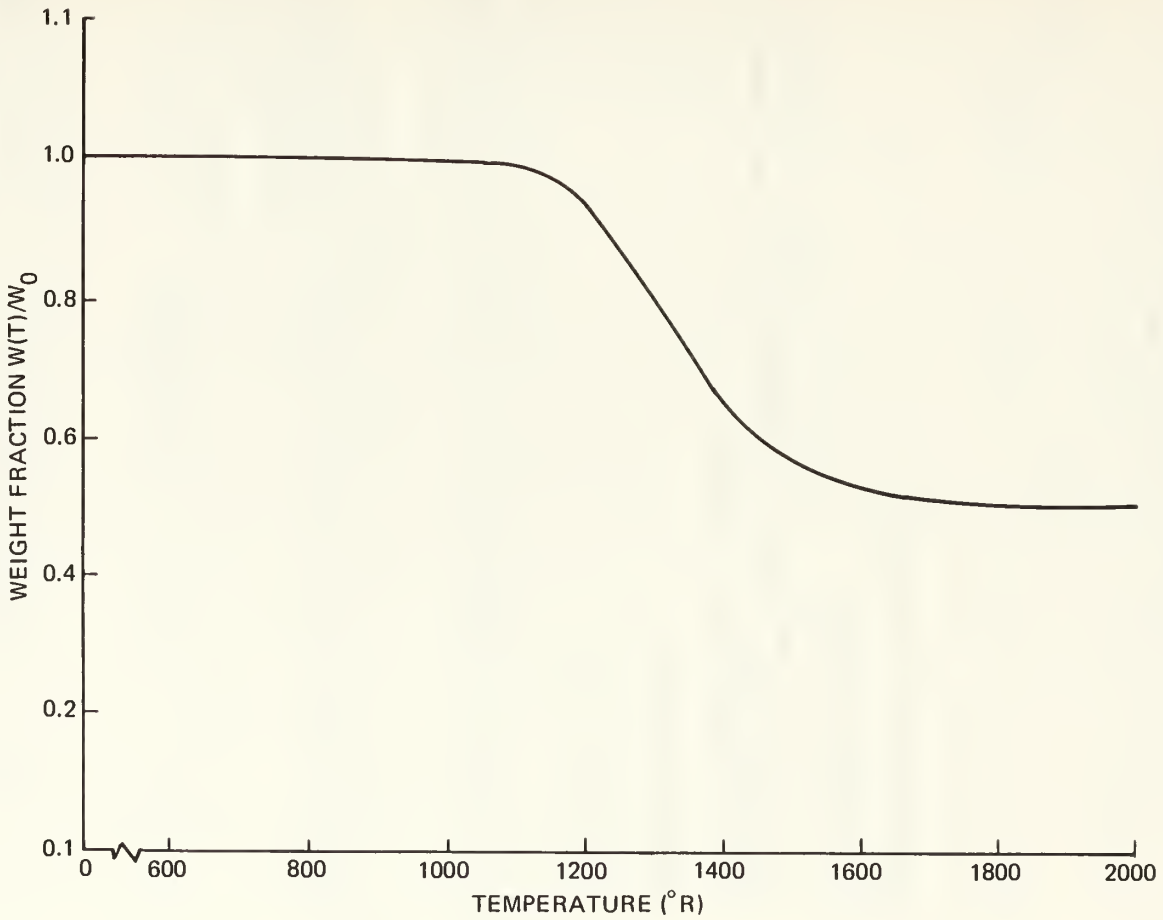


Figure 2.3. Thermogravimetric data for typical charring ablation material.

The Arrhenius Equation named after Sweden's Svante Arrhenius, a Nobel prize winner in chemistry in 1903, is really a class of equations which predicts the effects of temperature on the reaction rate of a chemical process. In its simplest form the equation looks like[14]

$$K = A \cdot e^{-E/RT} \tag{2-20}$$

where

K = the reaction rate constant

A = the frequency factor

E = the activation energy or the amount of energy in excess of the average energy level which the reactants must possess in order to proceed in a reaction

R = the gas constant

T = the temperature

Although Eq. (2-20) is almost 80 years old, its accuracy in predicting reaction rate dependency on temperature is so good that it has found wide applications in a great number of reaction kinetics problems.[14]

The original version of STAB II did not use Arrhenius-type equations, but because of their general success in modeling the production of pyrolysis gases, Dr. Curry incorporated them into the current version of the program. In the program, the calculation of the production of pyrolysis gases is performed in subroutines ABLATE and ABL2. The equation used for this purpose has the following basic form

$$\frac{\partial \dot{m}_g}{\partial x} = (CA)\left(\frac{\rho_i - \rho_c}{\rho_v - \rho_c}\right)^{SN} e^{-XB/T_i} \tag{2-21}$$

where

$\dot{m}_g$ = the mass flow of the pyrolysis gas

x = the axial direction of the gas flow

CA = the coefficient of the Arrhenius equation

$\frac{\rho_i - \rho_c}{\rho_v - \rho_c}$ = the density of the i^{th} node; ρ_c is the density of the char, and ρ_v is the density of the virgin material

SN = the reaction order for the Arrhenius equation

XB = the activation energy of the Arrhenius equation

T_i = the temperature of the i^{th} node

The variable CA corresponds directly with the variable A of Eq. (2-20), the frequency factor. And the variable XB corresponds directly with variable E of Eq. (2-20), the activation energy. The variable SN is not found in Eq. (2-20). It is an added factor called the reaction order and did not influence the results of this thesis since it was always assigned equal to one. The proper units for the variables of Eq. (2-21) are shown in Appendix B.

Another subroutine in STAB II which uses an Arrhenius expression is subroutine COEFF. One of the terms of an energy balanced performed in this subroutine is

$$(HV)\left(\frac{\Delta x}{2}\right)(CA)(\rho_i - \rho_c)^{SN} e^{-XB/T_i} \qquad (2\text{-}22)$$

All the terms of Eq. (2-22) are the same as in Eq. (2-21), except the heat of degradation, HV, is added. This variable is the endothermic energy necessary to make the material chemically degrade. The units of HV are Btu/lbm. The remaining terms in Eq. (2-22) combine to calculate the mass flow of the pyrolysis gases. The units are of lbm/ft^2-s. The

pyrolysis gases are the agents which remove the absorbed heat of degradation out of the material and the final units of Eq. (2-22) are a heat flux, Btu/ft^2-s.

The determination of the frequency factor, CA, and activation energy, XB, is a somewhat complicated task which is completely described in Reference (15). Basically, these coefficients can be calculated with the results of the TGA data for a material in question. Reference (15) describes five different methods to interpret the TGA data in order to determine the values of CA and XB. As will be discussed later in this thesis, TGA data was not immediately available for the intumescent material, Firex 2373. Therefore, this author's greatest effort involved determining the correct values of CA and XB in order for the computer model to match experimental results. In other words, given experimental results, values of CA and XB were deduced to make the model predict the experiment. This researcher discovered that variations in CA, and more importantly XB, had very significant effects on the output of the model. It is worth noting that although these two factors have strong influences on the results of the model, an examination of Reference (15) indicates that these coefficients can reasonably be determined experimentally to accuracies only on the order of plus or minus 1000 per cent.

The STAB II User's Manual explains the mathematical simulation of several other ablative phenomena such as the calculation of the hot wall convective heat flux. Since most of these phenomena are only associated with hyperthermal reentry applications and are not pertinent to application of a low, radiative heat flux, their explanations are not included in this thesis.

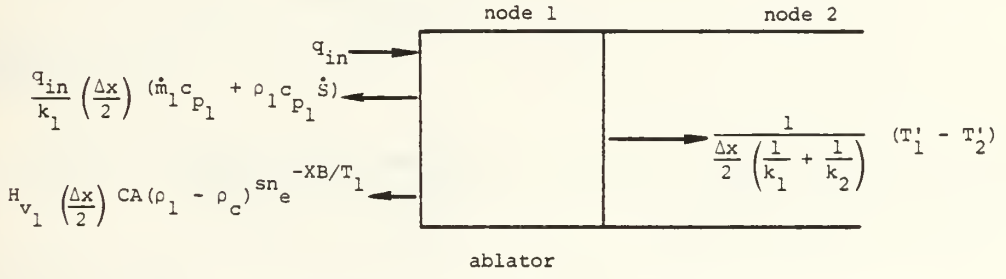
2.2.5 Difference Form of the Energy Equation

The difference representation of the energy equation is formulated differently for interior nodes and boundary nodes. The following paragraphs detail the difference equations programmed into STAB II for the

various nodes. Note the next subsections are taken directly from information provided in pages 9 through 19 of Chapter One of The STAB II User's Manual. Also the prime, "'", denotes the temperature at the next time step.

2.2.5.1 Energy Balances for the Ablation Material

2.2.5.1.1 The energy balance for the surface node (i=1)



$$\rho_1 c_{p_1}\left(\frac{\Delta x}{2}\right)\frac{(T_1' - T_1)}{\Delta t} = q_{in} - \frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_1}+\frac{1}{k_2}\right)}(T_1' - T_2')$$

$$- \frac{q_{in}}{k_1}\left(\frac{\Delta x}{2}\right)(\dot{m}_1 c_{p_1} + \rho_1 c_{p_1}\dot{S})$$

$$- H_{v_1}\left(\frac{\Delta x}{2}\right)CA(\rho_1 - \rho_c)^{sn_e}e^{-XB/T_i} \qquad (2\text{-}23)$$

Rearranging Eq. (2-23) to the form of subroutine COEFF and grouping temperature coefficients yields

$$-\left[\rho_1 c_{p_1}\left(\frac{\Delta x}{2\Delta t}\right) + \frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_1} + \frac{1}{k_2}\right)}\right] T_1'$$

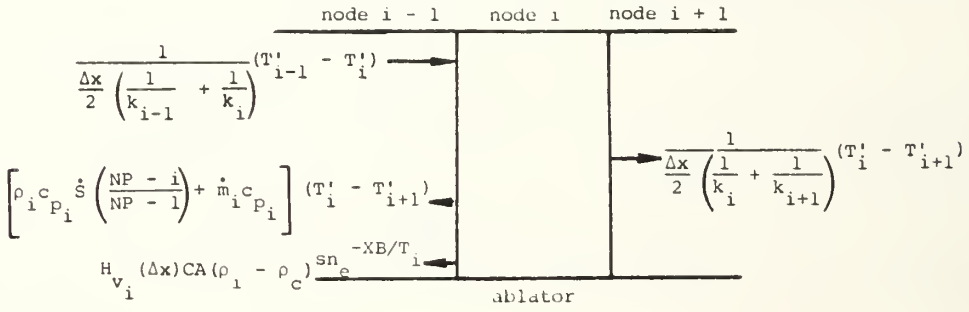
$$+ \left[\frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_1} + \frac{1}{k_2}\right)}\right] T_2' = -\rho_1 c_{p_1}\left(\frac{\Delta x}{2\Delta t}\right) T_1 - q_{in}$$

$$+ \frac{q_{in}}{k_1}\left(\frac{\Delta x}{2}\right)(\dot{m}_1 c_{p_1} + \rho_1 c_{p_1} \dot{S})$$

$$+ H_{v_1}\left(\frac{\Delta x}{2}\right) CA(\rho_1 - \rho_c)^{sn} e^{-XB/T_1} \qquad (2\text{-}23a)$$

Note that $\dot{S}$ is the surface recession which was set to zero in all the applications of this thesis.

2.2.5.1.2 The Energy Balance for the Interior Nodes (i=2, NP-1)



$$\rho_i c_{p_i} \Delta x \frac{(T_i' - T_i)}{\Delta t} = \frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_{i-1}} + \frac{1}{k_i}\right)} (T'_{i-1} - T_i') - \frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_i} + \frac{1}{k_{i+1}}\right)} (T_i' - T_{i+1}')$$

$$- \left(\rho_i c_{p_i} \dot{S}\left(\frac{NP - i}{NP - 1}\right) + \dot{m}_i c_{p_i}\right)(T_i' - T_{i+1}')$$

$$- H_{v_i} (\Delta x) CA (\rho_i - \rho_c)^{sn} e^{-XB/T_i}$$

(2-24)

Rearranging Eq. (2-24) gives

$$\left[\frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_{i-1}} + \frac{1}{k_i}\right)}\right] T'_{i-1}$$

$$- \left[\frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_{i-1}} + \frac{1}{k_i}\right)} + \frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_i} + \frac{1}{k_{i+1}}\right)}\right.$$

$$\left. + \rho_i c_{p_i} \dot{S}\left(\frac{NP - i}{NP - 1}\right) + \dot{m}_i c_{p_i} \rho_i c_{p_i} \frac{\Delta x}{\Delta t}\right] T_i'$$

$$+ \left[\frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_i} + \frac{1}{k_{i+1}}\right)}\right.$$

$$\left. + \rho_i c_{p_i} \dot{S}\left(\frac{NP - i}{NP - 1}\right) + \dot{m}_i c_{p_i}\right] T'_{i+1} = -\rho_i c_{p_i} \frac{\Delta x}{\Delta t} T_i$$

$$+ H_{v_i} (\Delta x) CA (\rho_i - \rho_c)^{sn} e^{-XB/T_i}$$

(2-24a)

NP is the total number of nodes selected in the input statement.

2.2.5.1.3 The Energy Balance for the Last Node in the Ablation Material (NP) and the First Node in the Backup Structure (1,1)

In order to interface

$$T'_{NP} = T'_{1,1} \tag{2-25a}$$

In the backup structure materials are designated "i" and nodes "j".

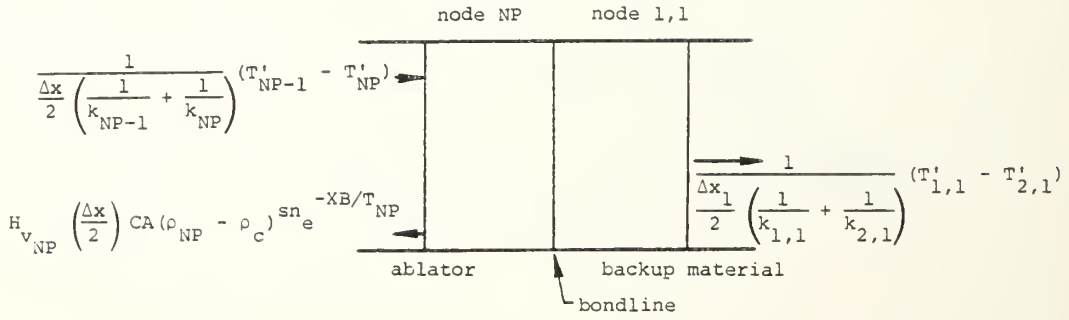
$$\Delta x = \Delta x_i \tag{2-25b}$$

$$\rho = \rho_i \tag{2-25c}$$

$$c_p = c_{p_{j,1}} \tag{2-25d}$$

$$k = k_{j,i} \tag{2-25e}$$

The energy balance is as follows



$$\left[\rho_{NP}c_{p_{NP}}\left(\frac{\Delta x}{2}\right) + \rho_1 c_{p_{1,1}}\left(\frac{\Delta x_1}{2}\right)\right]\frac{(T'_{NP} - T_{NP})}{\Delta t} = \frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_{NP-1}} + \frac{1}{k_{NP}}\right)}(T'_{NP-1} - T'_{NP})$$

$$- \frac{1}{\frac{\Delta x_1}{2}\left(\frac{1}{k_{1,1}} + \frac{1}{k_{2,1}}\right)}(T'_{1,1} - T'_{2,1})$$

$$- H_{v_{NP}}\left(\frac{\Delta x}{2}\right)CA(\rho_{NP} - \rho_c)^{sn}e^{-XB/T_{NP}} \qquad (2\text{-}26)$$

Upon rearranging, Eq. (2-26) becomes

$$\left[\frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_{NP-1}} + \frac{1}{k_{NP}}\right)}\right]T'_{NP-1}$$

$$- \left[\frac{1}{\frac{\Delta x}{2}\left(\frac{1}{k_{NP-1}} + \frac{1}{k_{NP}}\right)} + \frac{1}{\frac{\Delta x_1}{2}\left(\frac{1}{k_{1,1}} + \frac{1}{k_{2,1}}\right)}\right.$$

$$\left. + \rho_{NP}c_{p_{NP}}\left(\frac{\Delta x}{2}\right) + \rho_1 c_{p_{1,1}}\left(\frac{\Delta x_1}{2}\right)\right]T'_{NP}$$

$$+ \left[\frac{1}{\frac{\Delta x_1}{2}\left(\frac{1}{k_{1,1}} + \frac{1}{k_{2,1}}\right)}\right]T'_{2,1} = -\left[\rho_{NP}c_{p_{NP}}\left(\frac{\Delta x}{2\Delta t}\right) + \rho_1 c_{p_{1,1}}\left(\frac{\Delta x_1}{2\Delta}\right)\right]T_{NP}$$

$$+ H_{v_{NP}}\left(\frac{\Delta x}{2}\right)CA(\rho_{NP} - \rho_c)^{sn}e^{-XB/T_{NP}} \qquad (2\text{-}26a)$$

2.2.5.2 Energy Balances for the Back-Up Structure Materials

Note: In this section subscripts indicate:

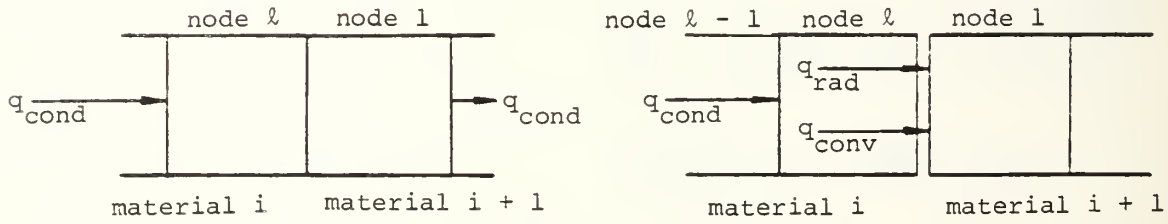
i = back-up material designation

j = node designation

Either of two situations may exist at the interface between two backup materials.

(1) For the condition of no air gap existing between the materials, heat transfer is considered only in the form of conduction.

(2) When an air gap exists between the materials, heat transfer by convection and radiation is considered.



(a) No air gap (b) Air gap

The difference equations for each of these conditions are detailed in the following subsections.

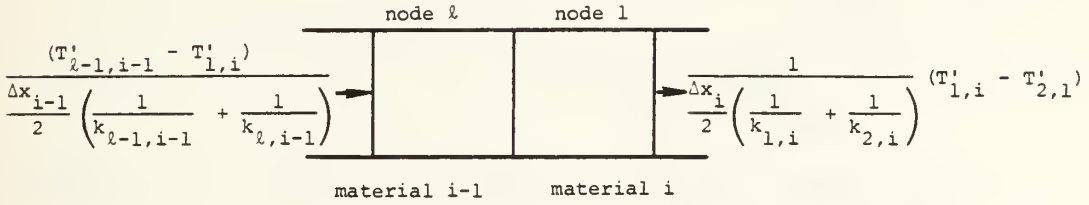
2.2.5.2.1 The Energy Balance for the First Node of the Backup Structure (j = 1, i - 1).

There is no air gap considered at the bondline. To interface with the last node of the heat shield (NP), $T_{1,1}$ is set equal to T_{NP}. The

energy balance is the same as that for node NP, and Eq. (2-26a) is used in subroutine COEFF.

2.2.5.2.2 The Energy Balance for an Interior Material Surface Node

(1) No air gap between materials. For boundary nodes of interior materials (j = 1, i > 1) the temperature $T'_{j,1}$ is made equal to the temperature of the last node (ℓ) in material i-1. The energy balance for an interior boundary node is



$$\left[\rho_i c_{p_{1,i}}\left(\frac{\Delta x_i}{2}\right) + \rho_{i-1} c_{p_{\ell,i-1}}\left(\frac{\Delta x_{i-1}}{2}\right)\right]\frac{(T'_{1,i} - T_{1,i})}{\Delta t} = \frac{1}{\frac{\Delta x_{i-1}}{2}\left(\frac{1}{k_{\ell,i-1}} + \frac{1}{k_{\ell-1,i-1}}\right)}(T'_{\ell-1,i-1} - T'_{1,i}) - \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{1,i}} + \frac{1}{k_{2,i}}\right)}(T'_{1,i} - T'_{2,i}) \quad (2\text{-}27)$$

Rearranging Eq. (2-27) yields

$$\left[\frac{1}{\frac{\Delta x_{i-1}}{2}\left(\frac{1}{k_{\ell-1,i-1}}+\frac{1}{k_{\ell,i-1}}\right)}\right]T'_{\ell-1,i-1}$$

$$-\left[\frac{1}{\frac{\Delta x_{i-1}}{2}\left(\frac{1}{k_{\ell,i-1}}+\frac{1}{k_{\ell-1,i-1}}\right)}\right.$$

$$+\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{1,i}}+\frac{1}{k_{2,i}}\right)}+\rho_i c_{p_{1,i}}\left(\frac{\Delta x_i}{2\Delta t}\right)$$

$$\left.+\rho_{i-1}c_{p_{\ell,i-1}}\left(\frac{\Delta x_{i-1}}{2\Delta t}\right)\right]T'_{1,i}$$

$$+\left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{1,i}}+\frac{1}{k_{2,i}}\right)}\right]T'_{2,i} = -\left(\rho_i c_{p_{1,i}}\Delta x_i+\rho_{i-1}c_{p_{\ell,i-1}}\Delta x_{i-1}\right)\frac{T_{1,i}}{2\Delta t}$$

(2-27a)

(2) Air gap between materials

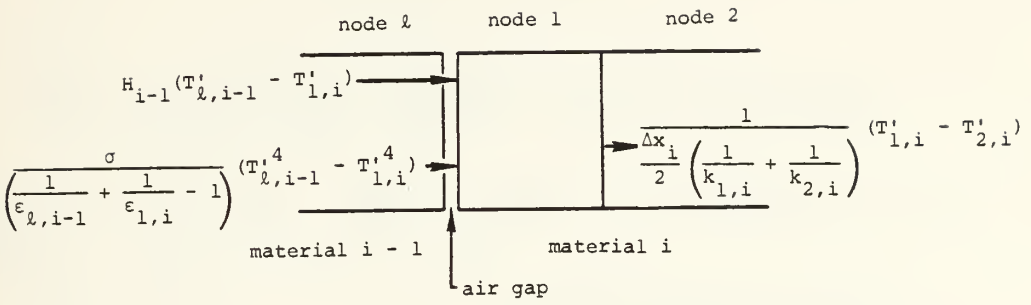
Note: Symbols for the radiation and convection terms in the energy balance are:

H = convective film coefficient

ε = emissivity of the material

σ = Stefan-Boltzmann constant

The energy balance is as follows



$$\rho_i c_{p_{1,i}} \frac{\Delta x_i}{2} \frac{(T'_{1,i} - T_{1,i})}{\Delta t} = - \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{1,i}} + \frac{1}{k_{2,i}}\right)} (T'_{1,i} - T'_{2,i}) + H_{i-1}(T'_{\ell,i-1} - T'_{1,i}) + \frac{\sigma}{\left(\frac{1}{\varepsilon_{\ell,i-1}} + \frac{1}{\varepsilon_{1,i}} - 1\right)} \left(T'^4_{\ell,i-1} - T'^4_{1,i}\right) \tag{2-28}$$

The fourth power unknowns (T'^4) can be eliminated by the following linearizations

$$(T')^4 = (T + \Delta T)^4 = T^4\left(1 + \frac{\Delta T}{T}\right)^4 \tag{2-29}$$

Let $Z \equiv \frac{\Delta T}{T}$

$$(T')^4 = T^4(1 + Z)^4 \tag{2-30}$$

If Z has an absolute value near zero, the following is true

$$(1 + Z)^4 \cong 1 + 4Z \tag{2-31}$$

Substituting into Eq. (2-29)

$$(T')^4 \cong (T)^4(1 + 4Z) = T^4\left(1 + 4\frac{\Delta T}{T}\right) = 4T^3T' - 3T^4 \tag{2-32}$$

Eq. (2-28) then becomes

$$\begin{aligned}\rho_i c_{p_{1,i}} \frac{\Delta x_i}{2} \frac{(T'_{1,i} - T_{1,i})}{\Delta t} = & - \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{1,i}} + \frac{1}{k_{2,i}}\right)} (T'_{1,i} - T'_{2,i}) \\ & + H_{i-1}(T'_{\ell,i-1} - T'_{1,i}) \\ & + \frac{\sigma}{\left(\frac{1}{\varepsilon_{\ell,i-1}} + \frac{1}{\varepsilon_{1,i}} - 1\right)} \\ & \left(4T^3_{\ell,i-1}T'_{\ell,i-1} - 3T^4_{\ell,i-1}\right. \\ & \left. - 4T^3_{1,i}T'_{1,i} + 3T^4_{1,i}\right)\end{aligned} \tag{2-33}$$

Rearranging Eq. (2-33) grouping temperature coefficients

$$\left[H_{i-1} + \frac{4\sigma T_{\ell,i-1}^3}{\left(\frac{1}{\varepsilon_{\ell,i-1}} + \frac{1}{\varepsilon_{1,i}} - 1\right)}\right] T'_{\ell,i-1}$$

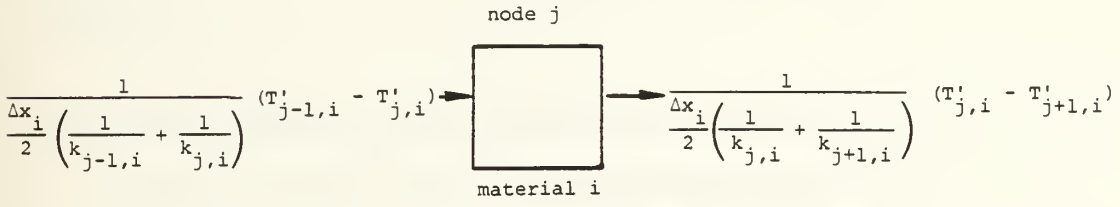
$$- \left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{1,i}} + \frac{1}{k_{2,i}}\right)} + \rho_i c_{p_{1,i}} \frac{\Delta x_i}{2\Delta t} + H_{i-1}\right.$$

$$\left. + \frac{4\sigma T_{1,i}^3}{\left(\frac{1}{\varepsilon_{\ell,i-1}} + \frac{1}{\varepsilon_{1,i}} - 1\right)}\right] T'_{1,i}$$

$$+ \left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{1,i}} + \frac{1}{k_{2,i}}\right)}\right] T'_{2,i} = -\rho_i c_{p_{1,i}} \left(\frac{\Delta x_i}{2\Delta t}\right) T_{1,i}$$

$$+ \frac{3\sigma}{\left(\frac{1}{\varepsilon_{\ell,i-1}} + \frac{1}{\varepsilon_{1,i}} - 1\right)} \left(T_{\ell,i-1}^4 - T_{1,i}^4\right) \qquad (2\text{-}33a)$$

2.2.5.2.3 The Energy Balance for the Interior Nodes of Any Material (j=2, NPM-1; i=1, NMB)



$$\rho_i c_{p_{j,i}} \Delta x_i \frac{(T'_{j,i} - T_{j,i})}{\Delta t} = \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{j-1,i}} + \frac{1}{k_{j,i}}\right)} (T'_{j-1,i} - T'_{j,i}) - \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{j,i}} + \frac{1}{k_{j+1,i}}\right)} (T'_{j,i} - T'_{j+1,i}) \quad (2\text{-}34)$$

Rearranging Eq. (2-34) gives

$$\left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{j-1,i}} + \frac{1}{k_{j,i}}\right)}\right] T'_{j-1,i} - \left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{j-1,i}} + \frac{1}{k_{j,i}}\right)} + \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{j,i}} + \frac{1}{k_{j+1,i}}\right)} + \rho_i c_{p_{j,i}}\left(\frac{\Delta x_i}{\Delta t}\right)\right] T'_{j,1} + \left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{j,i}} + \frac{1}{k_{j+1,i}}\right)}\right] T'_{j+1,i} = -\rho_i c_{p_{j,i}}\left(\frac{\Delta x_i}{\Delta t}\right) T_{j,i} \quad (2\text{-}34a)$$

2.2.5.2.4 The Energy Balance for the Last Node of an Interior Material.

(1) No air gap between materials. The equation for node ℓ, $i < NMB$ is the same as Eq. (2-27a) only the subscripts change.

$$\left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{\ell-1,i}}+\frac{1}{k_{\ell,i}}\right)}\right]T'_{\ell-1,i}$$

$$-\left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{\ell-1,i}}+\frac{1}{k_{\ell,i}}\right)}\right.$$

$$\left.+\frac{1}{\frac{\Delta x_{i+1}}{2}\left(\frac{1}{k_{1,i+1}}+\frac{1}{k_{2,i+1}}\right)}\right.$$

$$\left.+\rho_i c_{p_{\ell,i}}\left(\frac{\Delta x_i}{2\Delta t}\right)+\rho_{i+1}c_{p_{1,i+1}}\left(\frac{\Delta x_i}{2\Delta t}\right)\right]T'_{\ell,i}$$

$$+\left[\frac{1}{\frac{\Delta x_{i+1}}{2}\left(\frac{1}{k_{1,i+1}}+\frac{1}{k_{2,i+1}}\right)}\right]T'_{2,i+1} = -\left(\rho_i c_{p_{\ell,i}}\Delta x_i+\rho_{i+1}c_{p_{1,i+1}}\Delta x_{i+1}\right)\frac{T_{\ell,i}}{2\Delta t} \tag{2-35}$$

(2) Air gap between materials. The equation for the interior nodes of each material (j = NPM = k, i < NMB) is the same as Eq. (2-28), only the subscripts change.

$$\left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{k-1,i}}+\frac{1}{k_{k,i}}\right)}\right]T'_{k-1,i}$$

$$-\left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{k-1,i}}+\frac{1}{k_{k,i}}\right)}+\rho_i c_{p_{k,i}}\left(\frac{\Delta x_i}{2\Delta t}\right)+H_i\right.$$

$$\left.+\frac{4\sigma T^3_{k,i}}{\left(\frac{1}{\varepsilon_{k,i}}+\frac{1}{\varepsilon_{1,i+1}}-1\right)}\right]T'_{k,i}$$

$$+\left[H_i+\frac{4\sigma T^3_{1,i+1}}{\left(\frac{1}{\varepsilon_{k,i}}+\frac{1}{\varepsilon_{1,i+1}}-1\right)}\right]T'_{1,i+1}=-\rho_i c_{p_{k,i}}\left(\frac{\Delta x_i}{2\Delta t}\right)T_{k,i}$$

$$+\frac{3\sigma}{\left(\frac{1}{\varepsilon_{k,i}}+\frac{1}{\varepsilon_{1,i+1}}-1\right)}\left(T^4_{1,i+1}-T^4_{k,i}\right)$$

(2-36)

2.2.5.2.5 The Energy Balance for the Interior Node

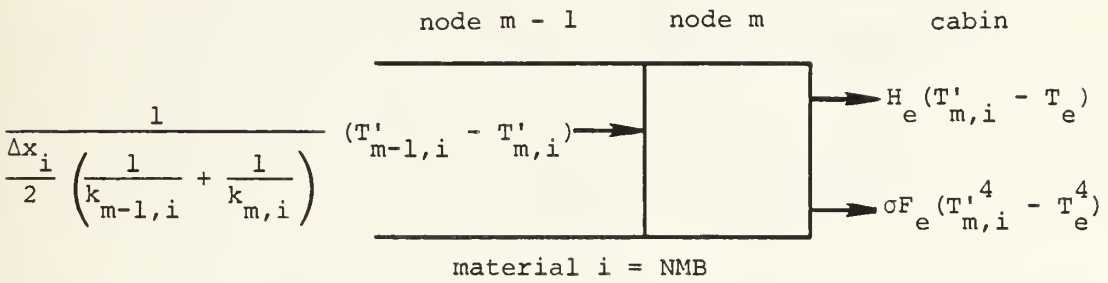
(1) For the last node in the final backup material (j = m, i = NMB) radiation and convection to the cabin are considered.

H_e = film coefficient to interior cabin environment

T_e = temperature of interior cabin environment

F_e = view factor and emissivity product for radiant heat transfer into the cabin.

The energy balance between the backup structure and the cabin is



$$\rho_i c_{p_{m,i}} \left(\frac{\Delta x_i}{2}\right) \frac{(T'_{m,i} - T'_{m,i})}{\Delta t} = \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{m-1,i}} + \frac{1}{k_{m,i}}\right)} (T'_{m-1,i} - T'_{m,i}) - H_e(T'_{m,i} - T_e) - \sigma F_e\left(T'^4_{m,i} - T_e^4\right) \quad (2\text{-}37)$$

Expanding the fourth order unknown by Eq. (2-32), Eq. (2-37) becomes

$$\rho_i c_{p_{m,i}} \left(\frac{\Delta x_i}{2}\right) \frac{(T'_{m,i} - T_{m,i})}{\Delta t} = \frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{m-1,i}} + \frac{1}{k_{m,i}}\right)} (T'_{m-1,i} - T'_{m,i}) - H_e(T'_{m,i} - T_e) - \sigma F_e\left(4T^3_{m,i}T'_{m,i} - 3T^4_{m,i} - T_e^4\right) \quad (2\text{-}37a)$$

Rearranging Eq. (2-37a) yields

$$\left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{m-1,i}}+\frac{1}{k_{m,i}}\right)}\right]T'_{m-1,i} - \left[\frac{1}{\frac{\Delta x_i}{2}\left(\frac{1}{k_{m-1,i}}+\frac{1}{k_{m,i}}\right)} + \rho_i c_{p_{m,i}}\left(\frac{\Delta x_i}{2\Delta t}\right) + H_e + 4\sigma F_e T^3_{m,i}\right]T'_{m,i} = -\rho_i c_{p_{m,i}}\left(\frac{\Delta x_i}{2\Delta t}\right)T_{m,i} - H_e T_e - \sigma F_e\left(3T^4_{m,i} + T^4_e\right) \quad (2\text{-}37b)$$

2.2.6 Formulation of the Momentum Equation

It may be desirable to determine the internal pressure distribution through the ablator in order to use it in conjunction with pressure dependent thermophysical properties of the char material.[8] If the momentum equation is uncoupled from the energy equation, the calculation of the internal pressure distribution may be performed in a straightforward manner. The option to determine the internal pressure distribution was not used in the pursuit of this thesis. Therefore further discussion on this topic will not be covered. Further discussion is available in Reference (8).

2.3 Adaptations

In using the STAB II program to model the response of an intumescent ablator, several changes were made to the original program. The purpose of this section is to briefly highlight some of the more pertinent changes this author has made.

2.3.1 General

In writing the request to Dr. Curry of NASA to obtain the STAB II program, this author entered the field of tape technology. Naturally there was some concern about the compatability of the UNIVAC 1108 system used at NASA and the AMDAHL 470 system used at CSDL. With the help of the computer staff at CSDL, all the appropriate tape parameters were requested from NASA. The received tape was placed on the CSDL system and it was discovered that the tape contained 81 characters per line; the AMDAHL system can only accommodate 80 characters per line. Jane Weinberg of the CSDL computer staff corrected this problem by writing an auxiliary program to strip off the last character of every line. Fortunately the last character on each line was part of an administrative line label and not pertinent to the FORTRAN program. Once the extra characters were stripped off, the program was loaded onto a disc where access became much easier.

As stated earlier, the changes in converting the program from FORTRAN V to FORTRAN 77 or VS FORTRAN were relatively minor. Once the program was placed into a partitioned data set (PDS), and each subroutine was made a member of the PDS; the program was compiled member by member. Upon the first compilation attempt only twelve of the fifty subroutines failed to successfully compile with the VS FORTRAN compiler. It was indeed fortunate that the two FORTRAN languages were basically compatible. Incidentally, no one at the CSDL computer facility was familiar with FORTRAN V, and in all probability, it is purely a UNIVAC extension of the more universally known FORTRAN IV.

When first running the program, this author encountered several division by zero or divide checks. These divide checks caused the program to have an abnormal end. To correct these problems, logic loops were inserted to allow for a flow path around any calculations where inputted variables would create division by zero. For instance when the variable SN was assigned the value 1.0, as it always was, the calculation

of TUL2 and TUL3 in the MAIN program involved division by zero. This was corrected by IF-THEN loops. See MAIN in program listing.

The most tedious changes in the program centered on the fact that VS FORTRAN only allows a four-element array for character variables while FORTRAN V allows a six-element array. This problem occurred in the subroutines where character output such as heading information is printed. The subroutines, INWRIT and TBLWRT, were the most affected by this difference in FORTRAN languages.

Another problem encountered was the fact that VS FORTRAN does not allow block data statements to be a part of an executable subroutine. Originally, all the data on the properties of the backup materials and values of the virgin and char conductivities and specific heat were included in the MAIN member of the program. To satisfy the VS FORTRAN compiler, this data was removed from MAIN and placed in a separate, nonexecutable member called MAINDA. MAINDA is a block data statement. For more information see Reference (16).

Finally, another change was the replacement of an internal NASA subroutine called CLOCK with an internal CSDL function called ITIME. This change was made in the MAIN member and the function is a running clock of the program execution time which is printed at the end of each run in the "case summary."

2.3.2 Deletions

The general philosophy used in making deletions to the program was to totally delete any unnecessary subroutines from the PDS. In the case of unnecessary statement lines in a needed subroutine, the philosophy was to "comment" the statement out of the program, thus leaving the statement available for any future applications. Whenever possible, statements which were "commented" out are noted in the program. For instance, the MAIN member has several statements which deal with a separate plotting

routine which was never obtained from NASA. These statements are commented out.

The following subroutines have been completely deleted from the original program:

(1) BLOCK DATA BLKFAC - This subroutine contains information on point locations for the Apollo space capsule.

(2) SUBROUTINE FACTR - FACTR calculates a convective heating rate multiplier, a radiative heating rate multiplier, a pressure ratio, and a wetted length for each trajectory point. These calculations applied only to the Apollo capsule.

(3) SUBROUTINE MORE - MORE calls the driver for the NASA plotting routine.

(4) SUBROUTINE PMES - PMES writes the plot number and required plotting time for NASA plotting routine.

(5) SUBROUTINE SCAL - SCAL determines the plotting scales for the dependent variables of the NASA plotting routine.

(6) SUBROUTINE TBLRED - TBLRED reads and stores the table input data. This subroutine proved to be extremely difficult to adjust to VS FORTRAN, and since it was not an absolute necessity, it was deleted.

(7) SUBROUTINE TPLOT - TPLOT writes the plot variables into a separate unit for the NASA plotting routine.

Note that these deleted subroutines are still available in the unedited versions of the STAB II program in either the PDS, ABLATE.FORT, or the sequential data set, SDS, STABII.BACKUP.FORT.

CHAPTER 3

COMPUTER PROCEDURES

The purpose of this chapter is to provide a description of several of the frequently used computer procedures which are required to run and edit the STAB II program on the CSDL computer system. This information is included for the use of the members of The Charles Stark Draper Laboratory, Inc. who may desire to utilize STAB II in the future. This material has no bearing whatsoever on the academic results of this thesis and therefore it may be skipped, if desired.

3.1 STABII.FORT

The partitioned data set, PDS, which contains the VS FORTRAN program STAB II is called STABII.FORT. This data set contains the main program driver, MAIN, and the forty-six separate subroutines of the program. In addition, there are two other members of STABII.FORT which are necessary to form an executable load module.[17] These extra members are $STABII and #STABII. The entire list of STABII.FORT is contained in Appendix G.

Access to STABII.FORT is very easy through the SPF editor. Any member (subroutine) can be quickly brought to the screen for editing by merely specifying the member's name in the SPF 2 entry panel. For example,

Library: STABII

Type: FORT

Member: ABLATE

will give one the subroutine ablate. The use of the powerful SPF editor will not be covered here. For more information on SPF see Reference (18). As a side note, the "Introduction to TSO" course is highly recommended for anyone not familiar with the CSDL system. Lesson four covers the SPF editor.

3.2 Compilation

There are several ways to compile the program, but the most inexpensive way is to use batch processing or to submit the compilation job in the background. The command to compile the PDS, STABIT.FORT, with VS FORTRAN in the background is:

```
XBFORTCL STABII.FORT FORT(V)
```

This is an interactive command which asks the user several questions concerning preprocessing and optimization level before it generates a job which submits the compilation in batch. You are not required to have any knowledge of the job control language, JCL, that is used to submit the compilation in batch. The computer asks if all the members should be compiled and which ones should be compiled if all the members are not requested. The output of the compilations is sent immediately to the printer. See Reference (17) for more details on this command.

Because the members MAIN and MAINDA were frequently changed and recompiled, job control language for submission of the compilations of these members was saved in two data sets, MCOMP.CNTL and MDCOMP.CNTL. With these two control data sets, the compilation jobs could easily be called and submitted, without having to go through the XBFORTCL command. The JCL for these members is on page 131 of Appendix C. Note that the message class for these two jobs is specified as an "H" which means the output is to be held in an output queue. This was done to allow the operator to quickly check whether or not the member compiled successfully without having to wait for the printed output. This saved considerable

time especially in that phase of the work when the conductivity of the virgin material was being frequently adjusted in the MAINDA member. Held output is available for screening with the SPF option 8.H.

3.3 Linking

Linking the program was done through the SPF option D.4.L. The three panels this option generates in the process of making the link are on pages 132 through 134 of Appendix C. Prior to performing the link, it is sometimes necessary to delete the old load data set called PGM.LOAD and create a new one; otherwise, the load data set may run out of region room. This author created a member of his CMD.LIST called PRELINK to delete and then recreate PGM.LOAD with one command, "PRELINK".

3.4 Running the Program

Once all the members have been successfully compiled and the program has been successfully linked, it can be executed. The program was submitted for execution in the background (BATCH) because of the savings in execution cost with a very minor effect on problem turnaround time. The JCL for two separate submissions of the execution job are seen on page 135 of Appendix C. In the first submission, STABII.CNTL(TESTRUN), all the system messages such as error messages or execution costs and the output results are printed into the same data set, "SYSOUT". In the second submission, the system messages go to SYSOUT while the output results go into the data set OUTPUT.DATA which then must be printed through a separate request. The sample output contained in Appendix E is an example of sending the results to the data set OUTPUT.DATA. Of course prior to submitting any runs of STAB II for execution, one should ensure that the input data contained in the data set INPUT.DATA (see Appendix D) is correct.

3.5 Plotting

The plotting routine used to generate the plots for this thesis is called PLOT4B. This is an external program maintained on the CSDL system which reads points from a designated data set and plots them on either the Versatec plotter or 9800 printer.

A typical plot data set is PLOT4.DATA as seen on page 136 of Appendix C. The PLOT4B routine allows up to three graphs to be plotted on any one plotting sheet. To use the routine for the PLOT4.DATA, the command is:

```
XPLOT4B  PLOT4.DATA
```

This plotting routine has many capabilities which are fully described in Reference (19). Since the plots are produced by connecting discrete points by straight lines, this author discovered that at least twenty to thirty data points are necessary to yield a smooth plot.

CHAPTER 4

PROGRAM TESTING

4.1 Introduction

Significant program testing was required to determine the input variables which were the most influential in affecting the output results. Determining these variables was of paramount importance if this author was to have any success in adjusting the computer model to match the experimental results of Lieutenant Joseph P. Marques. In addition to the parametric studies conducted on input variables, many of the program operating options were tried during the program testing phase.

In order to understand the direction of the entire testing phase, one must examine Figure 4.1, which is a plot of a 2-inch slug of Firex 2373 exposed to a 200-second burn. The burn was a constant heat flux of 10 Btu/ft^2-s. The plotted temperatures are of a thermocouple placed at 0.25 inch from the surface for both the experimental data, ETCL, and the computer-predicted results, XTCL. The values used in the computer to generate the XTCL curve were the original values NASA used in the program for the Apollo heat shield material. The only difference was that the conductivity of Firex 2373 was input and modeled over temperature as shown in Figure 4.2. Clearly, the model's predictions were too high, and therefore, the success of this thesis depended on making model adjustments which could greatly reduce the outputted thermocouple temperatures.

The purpose of this chapter is to qualitatively describe the results of the initial program testing. This information should be of

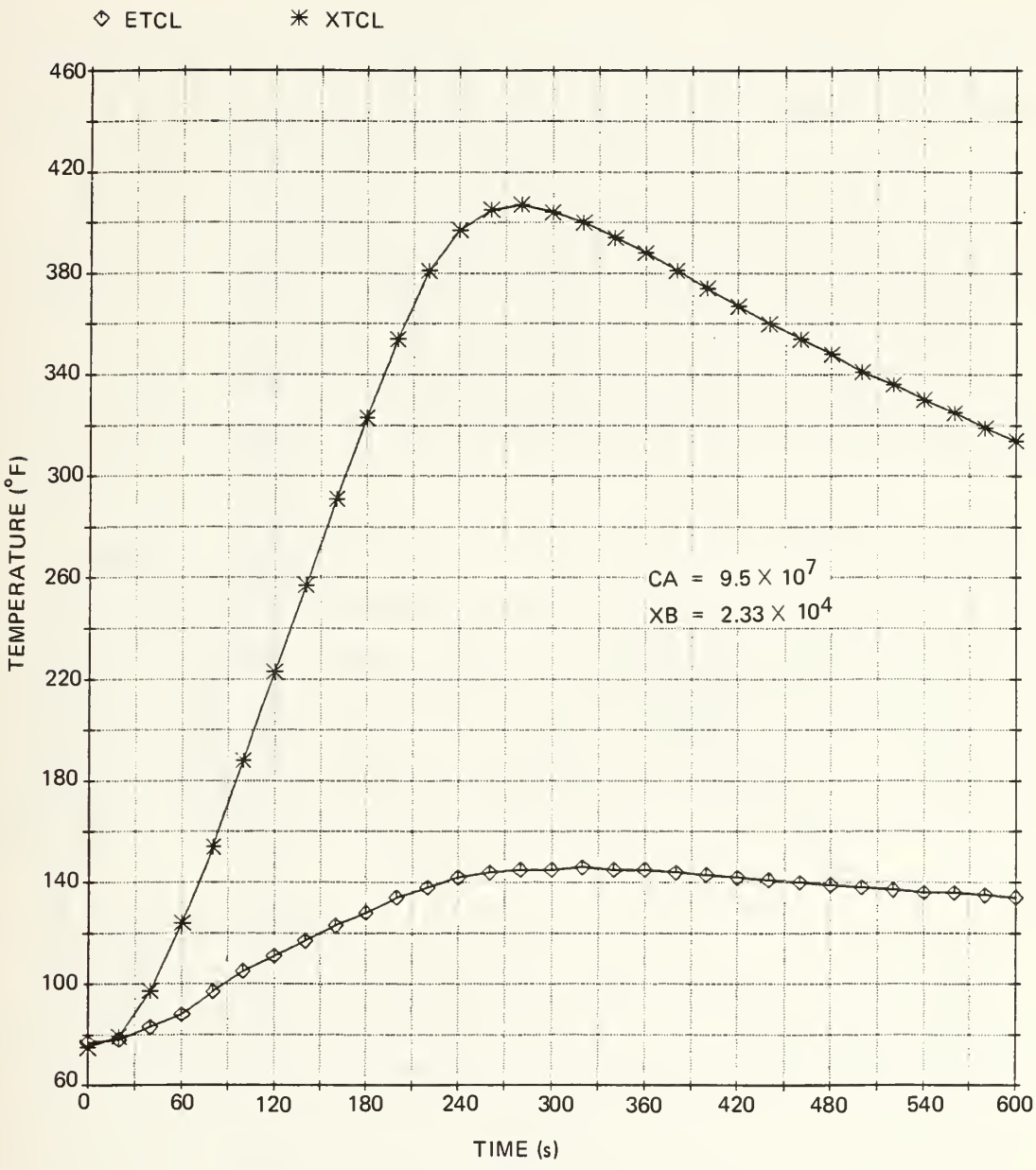


Figure 4.1. Plot of computer-predicted, XTCL, and experimental, ETCL, thermocouple temperatures versus time for a 2-inch slug of Firex 2373 exposed to a constant heat flux of 10 Btu/ft^2-s for 200 seconds. Thermocouple locations are 0.25 inches from the slug surface. Data for computer prediction based on values used in Apollo heat shield simulation.

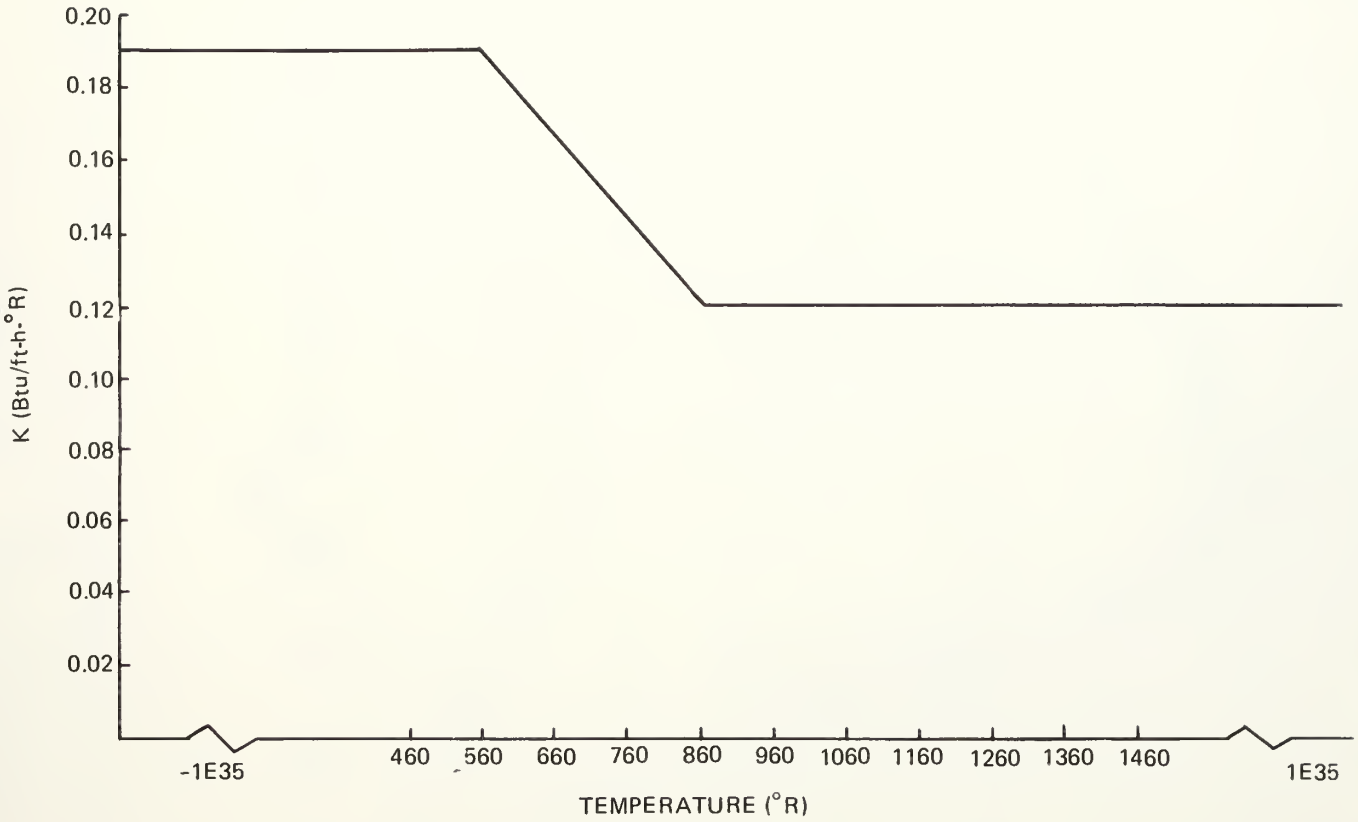


Figure 4.2. Conductivity model of virgin Firex 2373 used in generating the computer predictions of Figure 4.1.

practical value to anyone wishing to use STAB II to model other ablative materials. Although the discussion in this chapter is basically qualitative in nature, it is the result of over a hundred computer runs which could not possibly be included in this thesis.

The next chapter will provide more detailed information on how the key input variables affected the model output. Appendix B is an extensive table of all the NAMELIST (input) variables complete with proper units, computer dimensions, and author's comments. Since the complete description of the input variables is available in Appendix B, very little descriptive information of the variables will be included in the following discussion.

4.2 Number of Nodes, NP

The program can accommodate up to fifty nodes in the ablative material. In general, increasing the number of nodes increased the accuracy of the results. But using too many nodes can be costly and, in many cases, the extra cost is not merited. From experience, a nodal length in the ablative material of 0.06 inches worked well. This same nodal length is seen to be used in the "sample case" of Reference (8).

4.3 Time Step, DELTT

This is a critical input item because of the way in which the surface energy balance is performed. Because the surface energy balance is not an iterative process between time steps, surface temperature oscillations can occur.[10] These temperature oscillations can be removed by using a smaller time step in the calculations, particularly when the temperature is changing rapidly, as for example, when the burn is occurring. In the sample output seen in Appendix E, small surface node oscillations can be seen to begin at time equal to 120 seconds. These oscillations were later removed by decreasing DELTT from 1.0 to 0.1

second. Using the smaller time step removed the oscillations, and in this case, since the oscillations were not severe, the outputted thermocouple temperatures were not changed. By reducing the time step ten times, the execution cost per run increased from $2.00 to $8.00. For the application of this thesis, a time step of 1.0 second proved to be the best. Using a larger time step especially over the burn period, allowed the nodal temperatures to rise too quickly, thus making them inaccurate and much larger than experimentally observed.

One of the options in STAB II allows the user the ability to change the time step at various stages in the computer run. This would allow the capability of using a small time step during the dynamic burning period and a larger time step in the less critical cool-down period. This author tried many times to use this option but with no success. Whatever calculation interval was initially specified in the input statement, was the calculation interval used for the entire run. For more information on changing the time steps and print out intervals see the descriptions of variables DELTT, IPRC, NPTT, and TTABLE in Appendix B.

4.4 Heat of Degradation, HV

This variable is the endothermic energy necessary to make a material ablate and form pyrolysis gases. This absorbed energy is carried out of the material by the pyrolysis gases. The larger HV is, the less the thermocouple temperatures are because more heat is carried out of the material and less is conducted through it. Varying the value of HV indeed verified the previous statement. The important thing to note, however, is that significant increases in HV produced only minor decreases in the thermocouple temperatures. Therefore, HV was not considered a key variable to use in adjusting the model to match the experimental results. Conversations with Dr. Curry further confirmed HV to be of small importance and in the final Firex 2373 model, HV was set to the value advertised by the manufacturer, 2000 Btu/lbm.

4.5 Specific Heat of the Pyrolysis Gas, CPGAS

This variable has a similar effect on the results of the model as HV produced. Increasing CPGAS allows the pyrolysis gases to absorb more incident heat as they percolate out of the material, thereby allowing less heat to be conducted through the material. Thus, the thermocouple temperatures are effectively reduced. Again, however, significant increases in CPGAS produce only minor reductions in thermocouple temperatures. So like HV, CPGAS was not considered a key variable to use in adjusting the model. Since no other information was available, CPGAS was assumed to have the same value as used in the Apollo material.

4.6 Emissivity of the Virgin Material and Char, EMV, EMC

The emissivity of the virgin material is used in the calculation of the surface energy balance. Although a higher EMV reduces nodal temperatures slightly because less radiative heat enters the material, this effect of emissivity was considered to be very minor, and thus, EMV was not a key variable to use in adjusting the model. The emissivity of the char, EMC, was even less important due to the fact that little if any char formed on the surface of Firex in both the experimental and computer tests.

4.7 Reaction Order for the Arrhenius Equation, SN

Increasing the value of this variable had a modest effect in reducing the thermocouple temperatures. This benefit had a limited potential because increasing the value of SN above 3.0 produced uncontrollable surface temperature oscillations in which the surface temperatures would actually go to negative values. Most ablative materials, as evidenced by Reference (15), have a range of SN values which varies between 0.95 and 2.0. Because changing SN had such a modest impact on the computer results and because this author felt the least confident about changing SN from its Apollo value, a decision was made to keep SN at a

value of 1.0 and not to rely on SN to be a major contributor in adjusting the computer model.

4.8 Coefficient in the Arrhenius Equation, CA, or The Frequency Factor

Changing this variable did have a significant effect on the thermocouple temperatures and it became one of the key variables to use in adjusting the computer model. Increasing CA successfully reduced the thermocouple temperatures, but after a certain point was reached, any further increases in CA created temperature oscillations at the surface and underflow errors in the subroutine COEFF. Increasing the frequency factor increases the molecular collisions per minute, which in turn increases the probability of chemical degradation occurring. E.G. del Valle in his doctoral thesis, Reference (6), systematically studied the role both the frequency factor and the activation energy play in the ablation process. One of his conclusions was that the thickness of the reaction zone is controlled almost entirely by the frequency factor. So increasing the frequency factor effectively increases the amount of material which ablates thereby increasing the amount of heat carried out of the material by the pyrolysis gases. The end result is to decrease the amount of heat conducted through the material, thus reducing the thermocouple temperatures.

4.9 Activation Energy in the Arrhenius Equation, XB

This variable was even more effective than CA in changing the thermocouple temperatures. Unlike the case of CA, here the thermocouple temperatures were decreased by decreasing XB. Decreasing XB allows more material to ablate because the energy required to start the chemical ablative process is less. Or stated differently, del Valle discovered that the activation energy, XB, strongly influences the pyrolysis temperature.[6] Thus, for a given heat flux, decreasing XB allows the beneficial pyrolysis reaction to proceed sooner, and overall, more material will then ablate. As more material ablates, more heat

is carried away and less heat is conducted through the material. It will be shown in the next chapter that XB was, in fact, the most critical variable in adjusting the computer model. Its primary importance stems from its large sensitivity. Small decreases in XB produce very large decreases in thermocouple temperatures. And as can be seen again in Figure 4.1, significant thermocouple temperature reductions were needed to match the experimental results.

The enormous effects XB has on the computed results can be seen by reexamining Eq. (2-22).

$$HV\left(\frac{\Delta x}{2}\right)(CA)(\rho_i - \rho_i)^{SN} e^{-XB/T_i}$$

This equation is used in the subroutine COEFF to determine the temperatures at all the nodes. Decreasing XB significantly increases the entire term of Eq. (2-22). In calculating the nodal temperatures, this term is subtracted from several other terms so that the larger Eq. (2-22) is, the smaller the resulting nodal temperatures will be. For example, by reducing XB from its Apollo value of 23,300 to 17,000, the maximum surface temperature during a 200-second burn on a 2-inch slug of Firex 2373 was reduced from 1365 to 586°F. Reducing the surface temperature was, in effect, a primary means of adjusting the model because the surface temperature is the driving potential that ultimately determines the temperatures at all the other nodes.

4.10 Conductivity of the Virgin Material K(V)

The conductivity of the virgin material is input into the program through the data statement MAINDA. The conductivity is entered as a function of temperature into Table 99996. In the early program testing, the virgin conductivity was modeled as seen in Figure 4.2 and not altered. Although CA and XB were effective in moving the computer-predicted curves up and down in temperature, no parameter seemed effective in

altering the time the thermocouple temperature peaked, or in altering the slope of the thermocouple curve during the cool-down phase. After a long discussion with Dr. Curry, this author realized that the conductivity of the virgin material could be quite a significant tool in adjusting the model, particularly for the case of an intumescent ablator.

The conductivity model seen in Figure 4.2 clearly reflected the fact that the conductivity of an intumescent ablator decreases as it foams and swells during ablation. The data used to construct Figure 4.2 was obtained from the Dynatech Corp., which performed conductivity tests on a slab of unablated Firex 2373. Dynatech reported a room temperature conductivity of the virgin Firex to be 0.199 Btu/ft-h-°R while the manufacturer, Pfizer Inc., reported a virgin conductivity of 0.135 Btu/ft-h-°R. These two values bracketed the room temperature conductivity but unfortunately no information was available on the conductivity of intumesced Firex.

With the above information, this author constructed several potential models of the conductivity of Firex, and then ran the program with the different models. The results of these computer tests demonstrated that indeed the conductivity model was capable of adjusting both the time of thermocouple peak and the slope of the cool-down curve. The plan was to deduce the conductivity of the intumesced Firex by finding out what conductivity would be needed to match the experimental results. Note the conductivity of char would be equally important if more char formed.

The next chapter contains more on the conductivity modeling. In summary, the initial program testing identified three variables to be the most effective in adjusting the computer model. These variables were the frequency factor, CA, the activation energy, XB, and the conductivity of the virgin material.

4.11 Program Options

The following sections contain brief remarks concerning several of the options available in the STAB II program.

4.11.1 Multiple Runs

The program is supposed to have the capability of running several cases with one input data set in which the various cases are separated by a four-digit real number. The last case has the number "9999." after it. Note that once a variable is initialized in an input statement, it keeps that value until specifically reassigned. Unfortunately, this author could never successfully get this option to work, and therefore, only one case could be run at a time. The reason for this problem is believed to be the fact that the subroutine RESET was never included in any NASA-furnished information including the STAB II User's Manual. Without this subroutine, Dr. Curry suggested making a dummy subroutine called RESET to satisfy the MAIN routine call. This was done, but still, the original RESET must have some function in the multiple case option.

4.11.2 Thermocouple Driver

This option allows the user to drive the program by inputting the surface temperatures as a function of time instead of inputting the heat fluxes (heating rate driver). Again, this author had no success with this option. By using a surface pyrometer, Lt. Marques was able to obtain the surface temperature values over an entire burn sequence. When these temperatures were input under the thermocouple driver option none of the material ablated. It was noted that the surface temperatures inputted were close to the surface temperatures that are calculated when the heating rate driver is used. This problem was never brought to Dr. Curry's attention and this author has no idea for the reason behind this failure.

4.11.3 Multiple Backups

As mentioned earlier, the program can accommodate up to 12 back-up materials. During a conversation with Dr. Curry, both the author and Dr. Curry discovered that at least three backup materials have to be used to run the program. This fact is noted in the table of NAMELIST variables, Appendix B. For this thesis, three 1-inch air gaps were used as the backup materials since our group was reasonably certain that the backside of the experimental slug was almost perfectly insulated. In running the program for the 45-second burn on the 0.1875-inch water specimen, a 0.0625-inch aluminum plate was split into three backups. The point worth mentioning here is that the type of backup material did not seem to significantly change the results of the computed temperatures. This observation may only apply to the application of the program to our specific purpose.

4.11.4 Boundary Condition for the Last Node of Backup Material

For almost all the runs, the boundary condition between the last node of the backup material and the environment was perfect insulation or no heat exchange, QLOSS=0. Again, the insulation on the back of the experimental test samples was felt to be nearly perfect. This author tried setting QLOSS≠0., thus allowing heat exchange at the boundary and this change did not seem to have any effect on the output results.

CHAPTER 5

MODEL SELECTION AND THE DEMONSTRATION OF HOW THE KEY VARIABLES AFFECT THE MODEL RESULTS

5.1 Introduction

The primary purpose of this chapter is to present the computer model finally selected to predict the thermal response of Firex 2373 when exposed to a transient, low heat flux environment. In addition, each of the key variables—CA, XB, and the conductivity of the virgin material—will be examined for their individual influences on the model results. The presentation of this chapter may seem reversed because the selected model is discussed before the sections describing how the key variables individually affect the computer results, when, in fact, the model selection was based on all the understanding gained from the testing of these key variables. The reason for this format follows.

In performing dozens of tests on the model, this author quickly discovered that no key variable had an independent effect on the results of the model. In other words, similar effects on the output can be gained by changing XB or the conductivity or even by changing both of them together. Isolating each change and its subsequent effect on the results was difficult. The tendency was to make too many changes per run. By changing a single variable per run the above problem was avoided. So, after many program alterations, the model which most closely represented the experimental test results was selected. The many computer runs which supported this selection can not possibly be included in this thesis.

In order to clearly demonstrate the influence each of the key variables had on the model, it was decided to present the results of the chosen model first so that the results obtained by altering these variables could be compared to a standard.

Note that the following figures in this chapter are plots of computer predicted, XTCL, and experimental, ETCL, thermocouple temperature versus time for a 2-inch slug of Firex 2373 exposed to a constant heat flux of 10 Btu/ft^2-s for 200 seconds (Figures 5.1, 5.3, 5.5, 5.7, and Figures 5.10 through 5.14). In all cases, the thermocouple locations are 0.25 inches from the slug surface. Since this description is given here, it will not be repeated on each figure.

5.2 Reduction in the Conductivity of the Intumesced Virgin Material

Prior to presenting the selected model of Firex 2373, one intermediate result will be discussed. Test specimens of Firex 2373 clearly showed that the material expanded or swelled as it ablated. The intumesced material appeared to be mostly composed of air pockets with very little matrix material present. This author then decided to model the conductivity of the intumesced material as being close to that of air, thus giving the intumesced material a tremendous insulative capacity.

Before viewing the results of this new conductivity model, note that at this stage in the experimental matching, XB had been reduced from the value of 23,300 used in Apollo to 20,000, and CA had been increased from 9.5×10^7 to 9.5×10^9. The effects of these changes to CA, XB, and the conductivity model are seen in Figure 5.1. The conductivity model is seen in Figure 5.2. By now the computer predicted temperatures, XTCL, are seen to be getting closer to predicting the experimental temperatures, ETCL. The changes in XB and CA were mainly responsible for the closeness in temperatures, while the lower conductivity modeling of the intumesced material was responsible for the close match in the time of maximum temperature and the slope of the cool-down region of the curve. These results

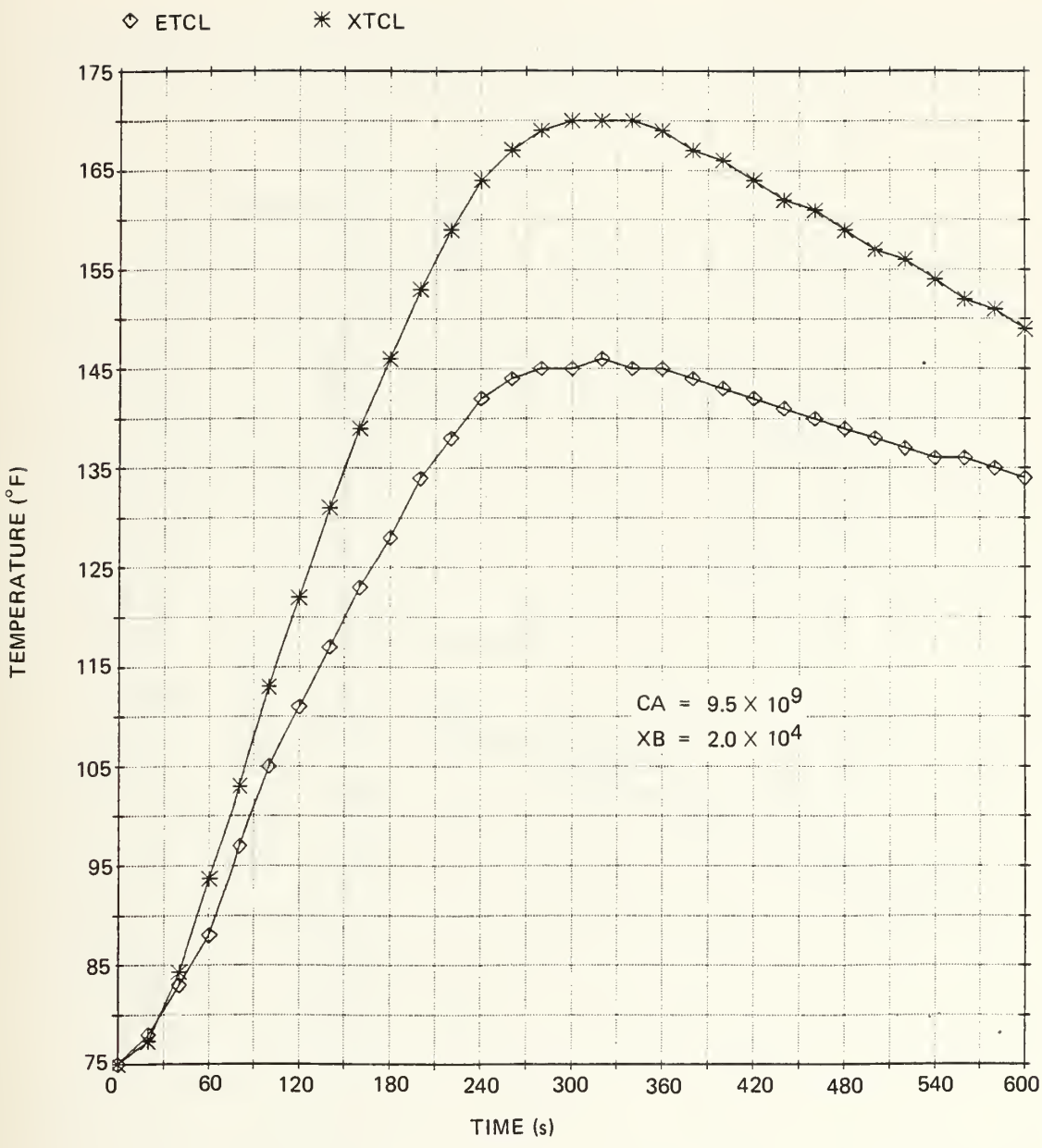


Figure 5.1. Intermediate result in attempting to match experimental results, ETCL.

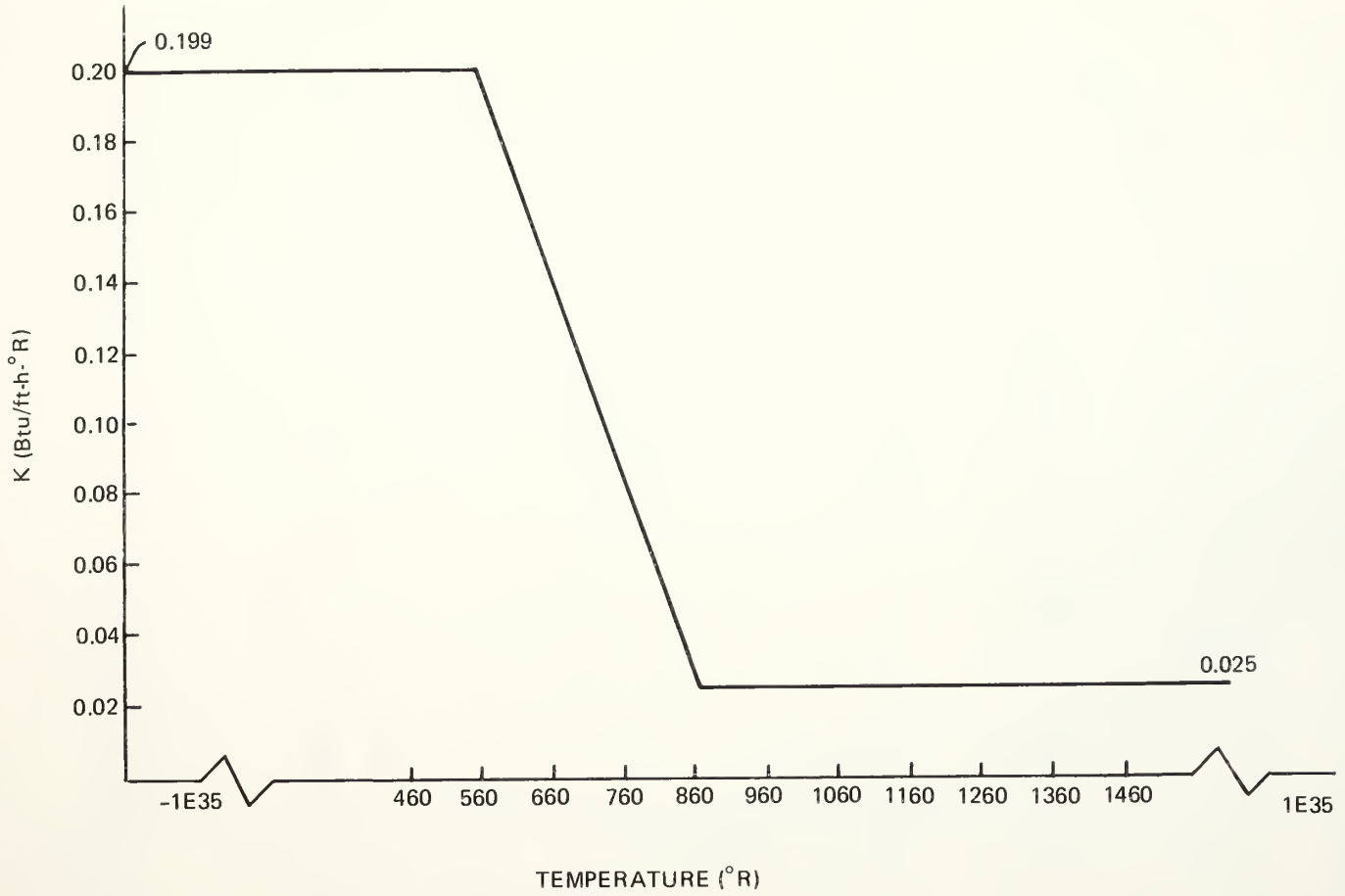


Figure 5.2. Conductivity model of virgin Firex 2373 used in generating the computer predictions of Figure 5.1.

were encouraging, although the author realized that modeling the conductivity of the intumesced material as the conductivity of air was somewhat unrealistic.

5.3 Model Selection

The model used to obtain the results of Figure 5.1 was adjusted through almost a trial and error procedure until the computer results almost exactly matched the experimental results as seen in Figure 5.3. In obtaining this almost identical match, CA was left at 9.5×10^9 and XB was reduced further to 16,800. Also, the conductivity of the nonintumesced Firex was modeled at 0.150 Btu/ft-h-°R. The conductivity of the intumesced Firex remained at 0.025 Btu/ft-h-°R. The graph of the conductivity model is shown in Figure 5.4. This model was thus selected as the model to use in predicting the response of Firex 2373 when exposed to a transient, low heat flux environment.

During the heating phase, which is the first two hundred seconds, the computer model does an especially good job in predicting the temperature at the 0.25-inch thermocouple. Notice that, after the burn is over, the computer models lower thermocouple temperatures but that the rate of cool down as judged by the slopes of the two curves appears to be the same. By comparing the values of CA and XB with values these variables have in several ablative materials as reported by Reference (20), the author feels that the selection of the values of these two variables was clearly within reason. Modeling, the nonintumescent virgin material as 0.150 Btu/ft-h-°R was also reasonable because it is in between the Dynatech and manufacturer's reported values. Again, modeling the intumesced virgin material so low may be an exaggeration, but this was necessary to match the slopes of the cool-down curves.

5.4 Demonstration of How Key Variables Affect the Results

The following sections describe how changes in CA, XB, and conductivity of the virgin material affected the model. In order to clearly

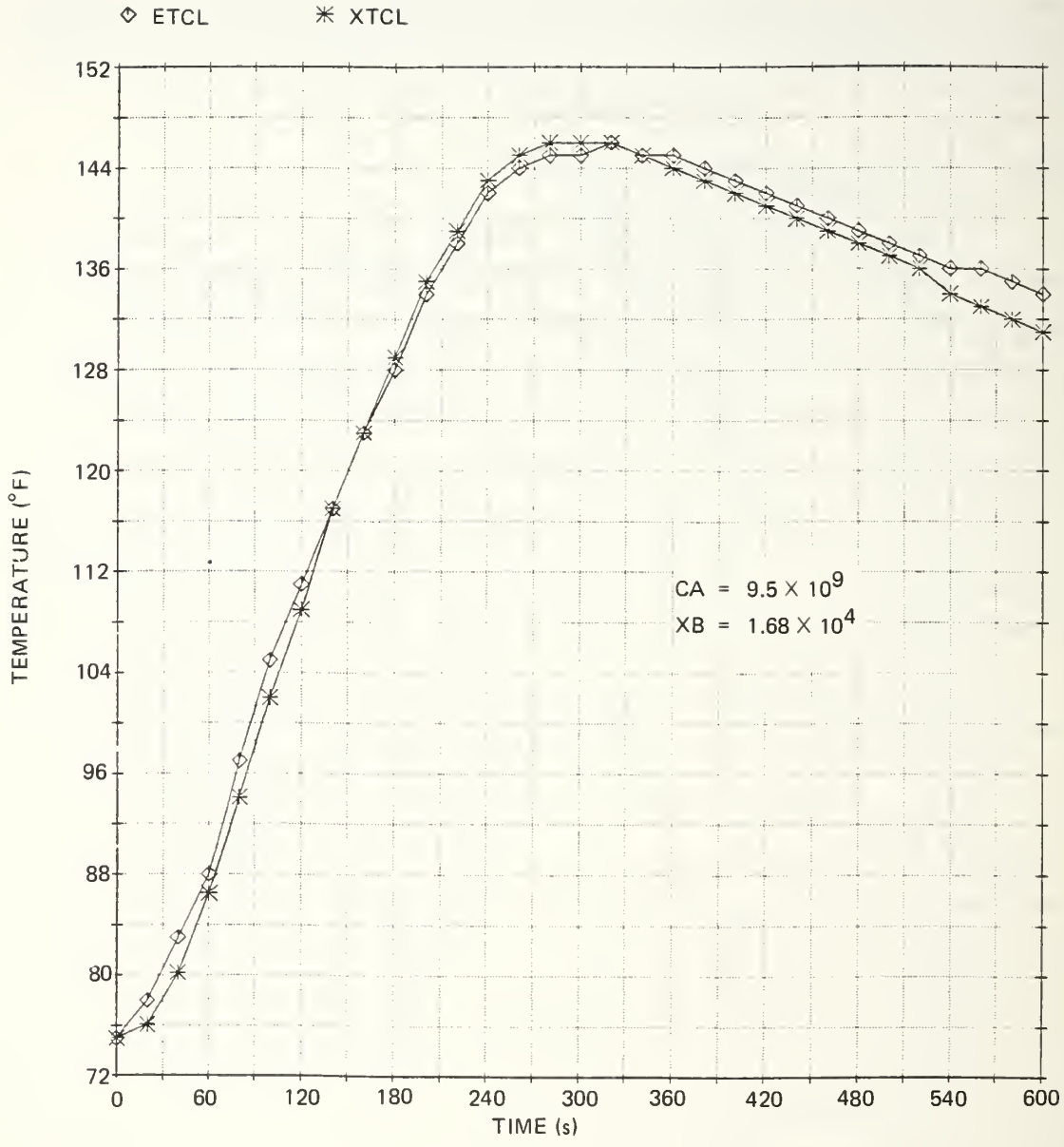


Figure 5.3. Computer predictions of the selected model.

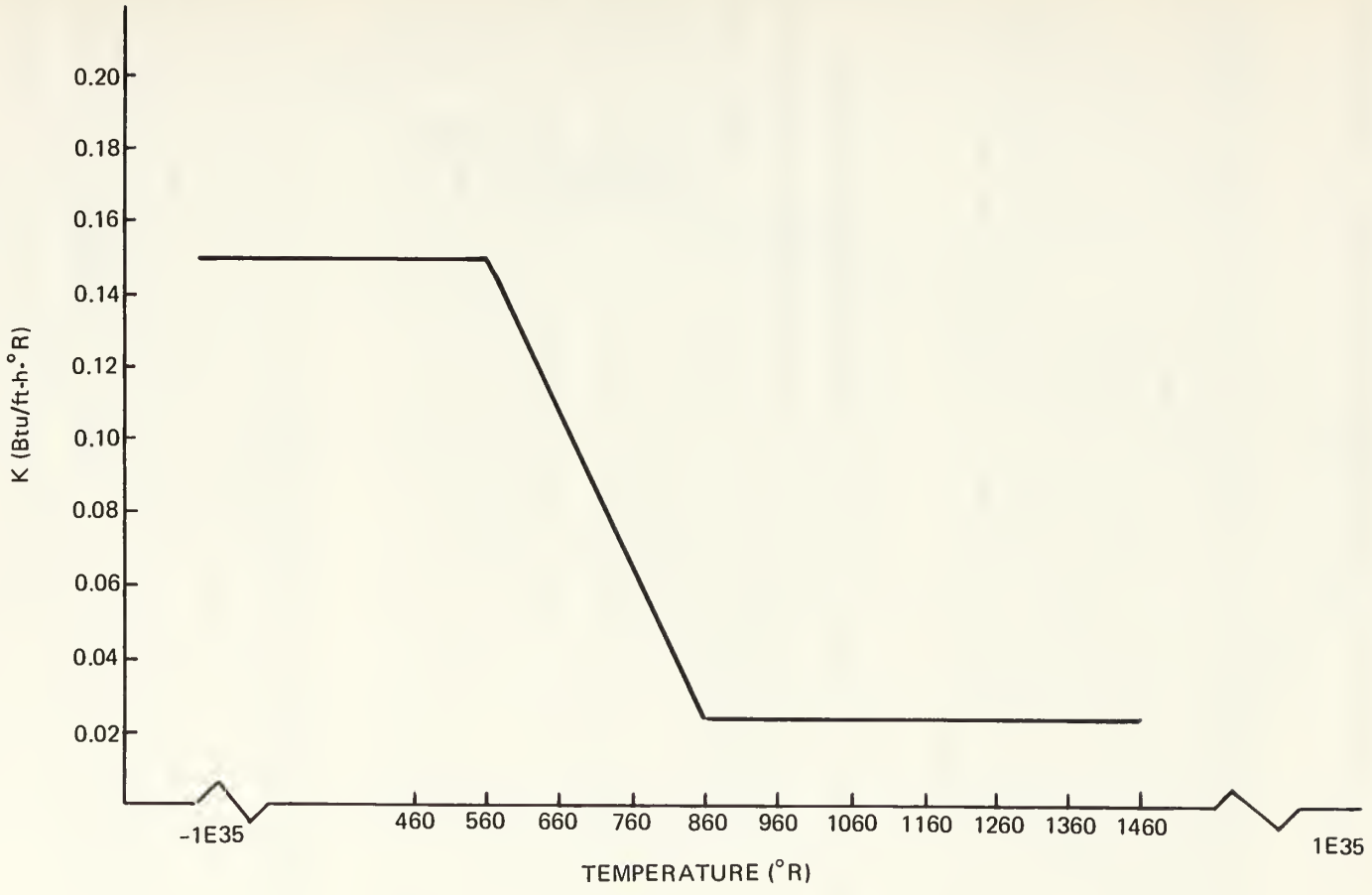


Figure 5.4. Conductivity model of virgin Firex 2373 used in the selected computer model.

demonstrate how each variable individually affected the model, only one variable was changed at a time in the following computer runs. The other variables in each run were kept at the same values used in the selected model.

5.4.1 Increase the Conductivity of the Nonintumesced Virgin Material

Figure 5.5 shows the result of increasing the conductivity of the nonintumesced virgin material from 0.150 Btu/ft-h-°R to 0.199 Btu/ft-h-°R. Figure 5.6 is a graph of the conductivity model for this run. The result of this increase is not only a rise in the peak temperature but also the time of maximum temperature occurs a little earlier than that of the experimental results.

5.4.2 Increase the Conductivity of the Intumesced Virgin Material

In this case, the conductivity of the intumesced virgin material is increased from 0.025 Btu/ft-h-°R to 0.080 Btu/ft-h-°R. Thus, the conductivity of the intumesced virgin is modeled as the conductivity of asbestos instead of air. The results of this change are seen in Figure 5.7 with the conductivity model shown in Figure 5.8. Because the vertical axis of Figure 5.7 covers a larger range than the vertical axis of Figure 5.5 or of Figure 5.3, it is at first hard to see that the result of increasing the intumesced virgin conductivity produces a maximum temperature larger than that of Figure 5.5. Also the time of maximum temperature is still too early.

5.4.3 Increase the Ablative Zone Thickness

One of the areas of question for almost all ablative materials is what is the temperature range in which the ablation occurs. For the case of Firex, the temperature range over which the intumescence occurs, and thus the conductivity decreases, was assumed to be about 300°R as seen in Figure 5.2. As the result of experimental observations, the temperature at which the intumescence started was about 100°F (560°R).

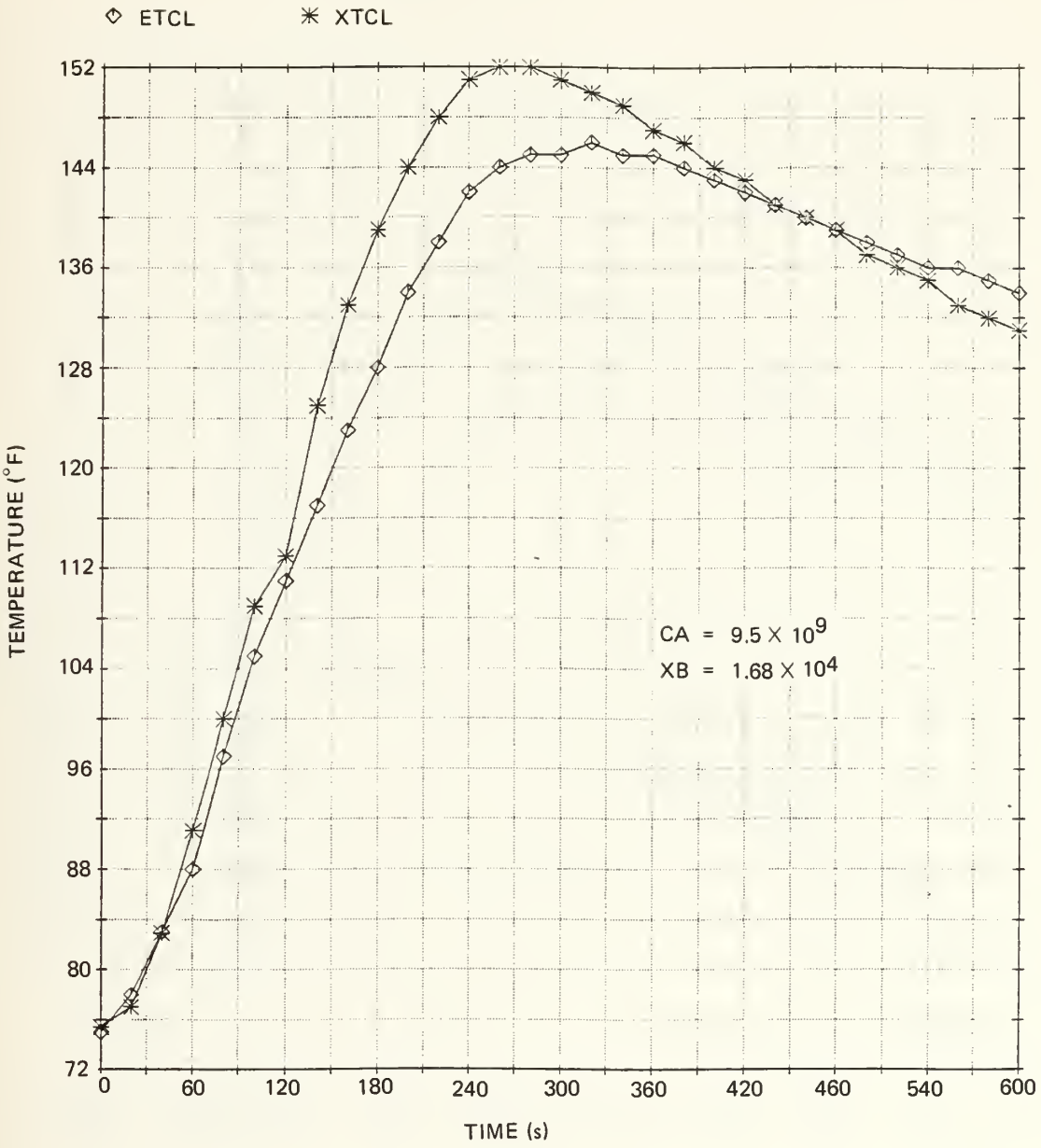


Figure 5.5. Increasing the conductivity of the nonintumesced virgin material.

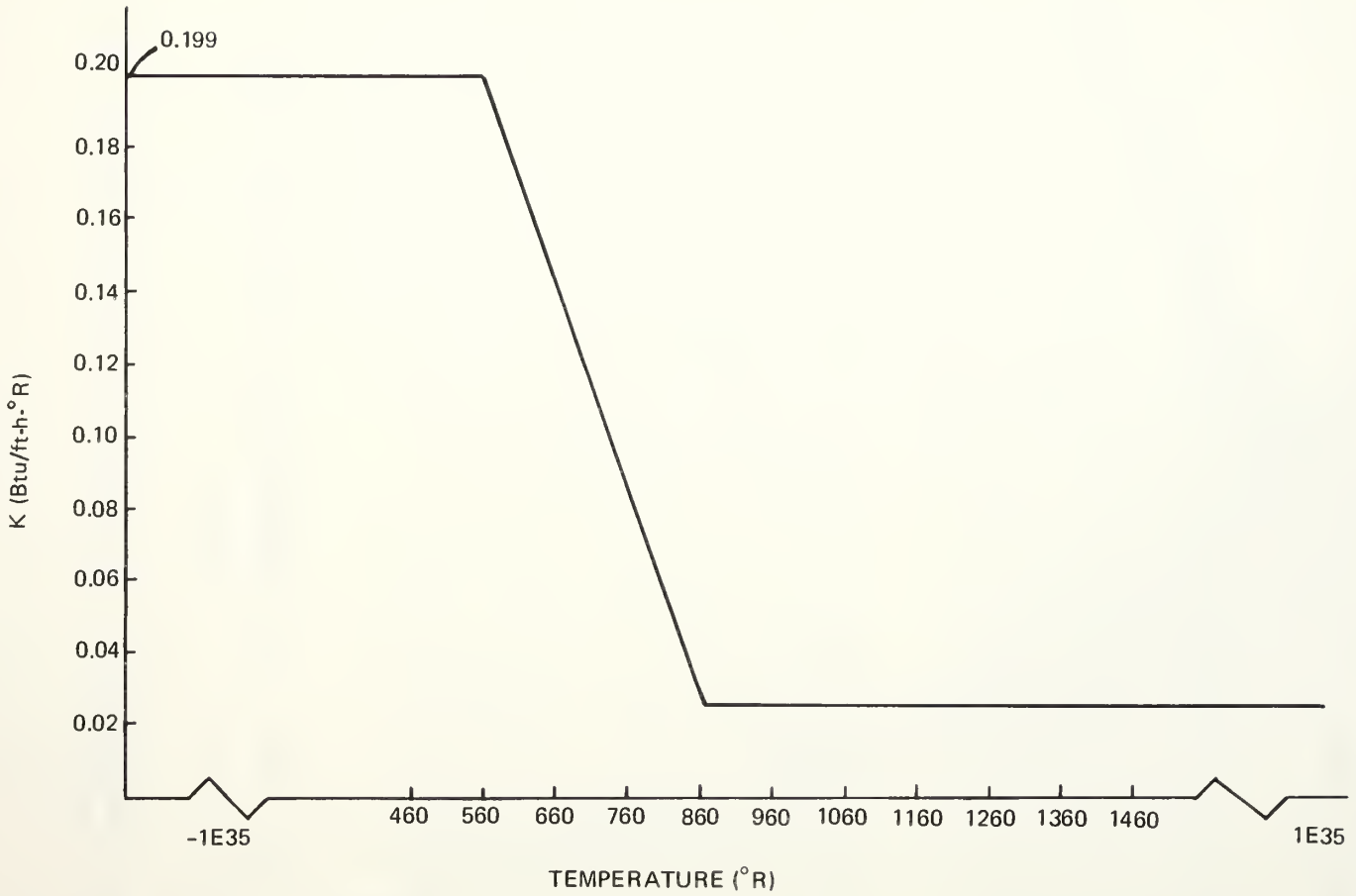


Figure 5.6. Conductivity model of virgin Firex 2373 used in generating the computer predictions of Figure 5.5.

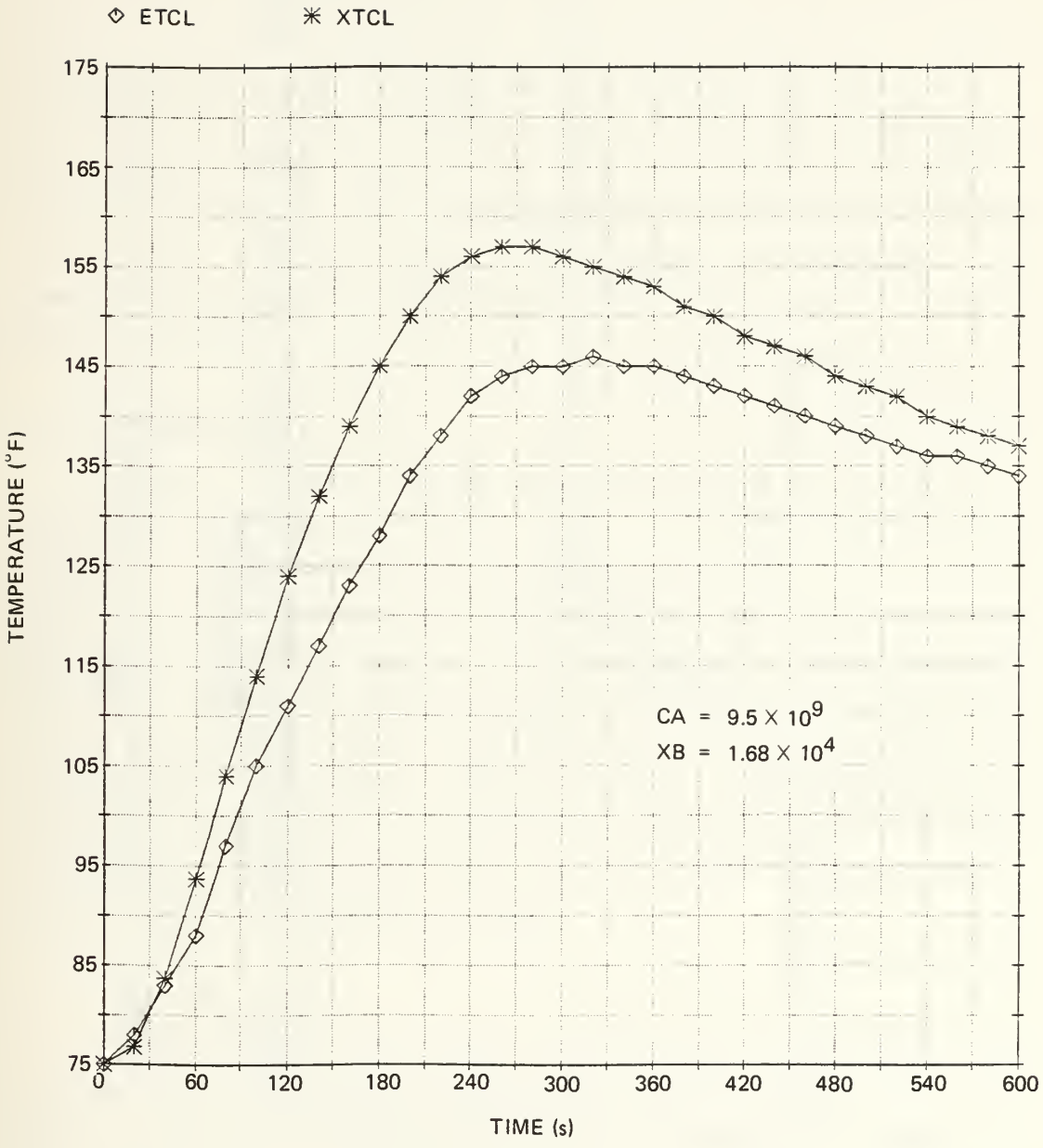


Figure 5.7. Increasing the conductivity of the intumesced virgin material.

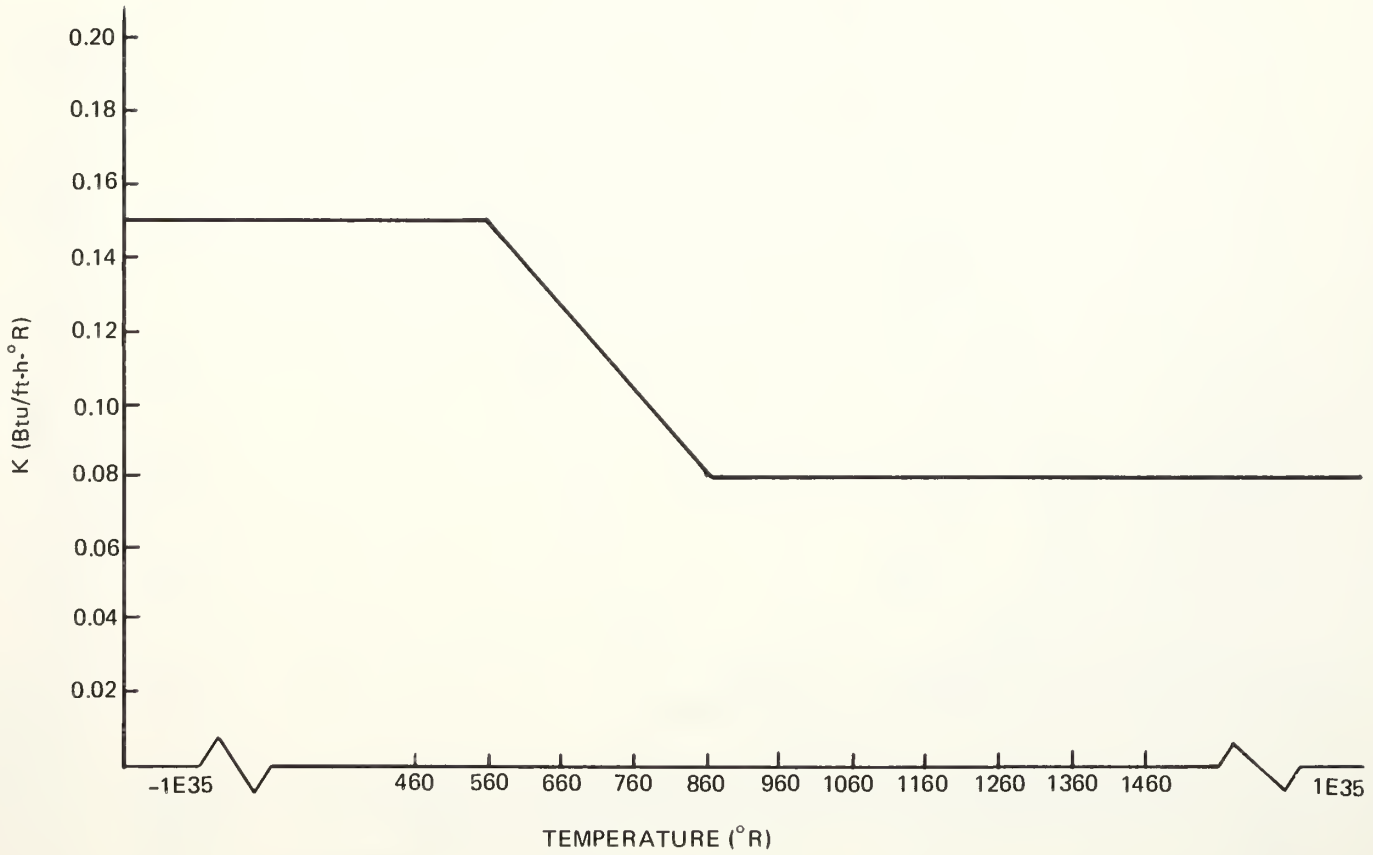


Figure 5.8. Conductivity model of virgin Firex 2373 used in generating the computer predictions of Figure 5.7.

In order to see the effects of increasing the temperature range of intumescence, the conductivity of the virgin Firex was modeled as seen in Figure 5.9. As seen in the figure, the intumesced temperature region was between 560 and 1060°R. The results of this change are seen in Figure 5.10. Not only is the maximum temperature much higher than experimentally measured, but also the time of maximum temperature is much earlier. The problem here is that by increasing the intumescent temperature zone, the insulative effect of the intumesced material occurs much slower, and thus the peak temperature of the 0.25-inch thermocouple is higher and earlier.

5.4.4 Increase XB

Figure 5.11 shows the results of increasing XB from its previously selected value of 16,800 to 23,000. The conductivity model used in this run is the same one used in the selected model as seen in Figure 5.4. Clearly, increasing XB greatly increases the thermocouple temperatures. As noted in Chapter 4, increasing XB effectively increases the surface temperature and this increase transmits itself through the rest of the material. Notice that the time of maximum temperature occurs later when XB is increased. Normally this effect is only associated with conductivity changes in the virgin material. This helps illustrate that in matching the experimental results with the computer program, this author found few independent variables.

5.4.5 Decrease in XB

Decreasing XB lowers the surface temperature and subsequent thermocouple temperature values. Figure 5.12 shows this effect. For this run XB was reduced from 16,800 to 16,000. As mentioned in Section 4.9, this characteristic of XB was the most important factor in finally matching the experimental results. The conductivity model for this run is seen in Figure 5.4.

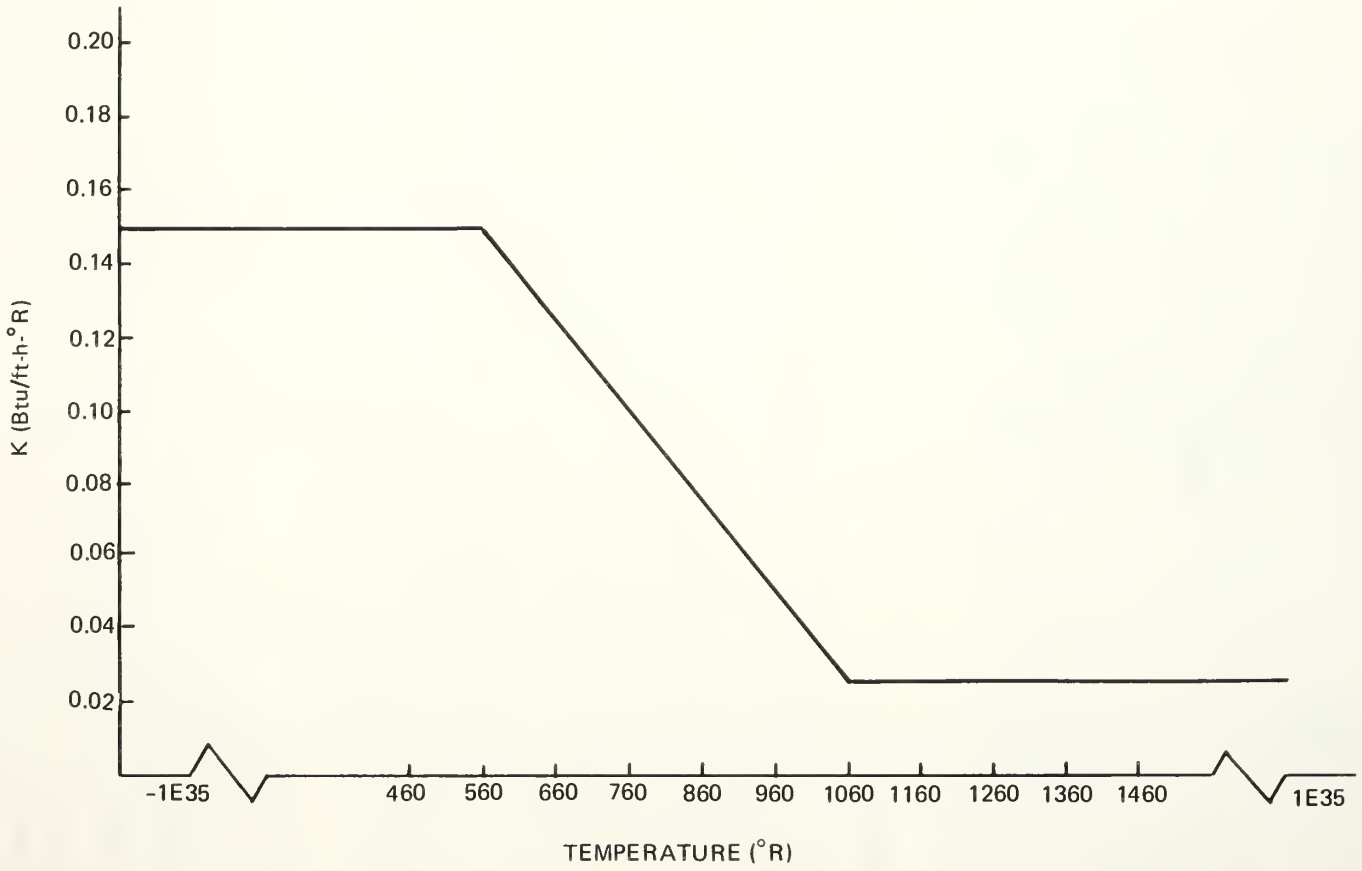


Figure 5.9. Conductivity model of virgin Firex 2373 with an increased temperature range of the ablative zone. Computer predictions are in Figure 5.10.

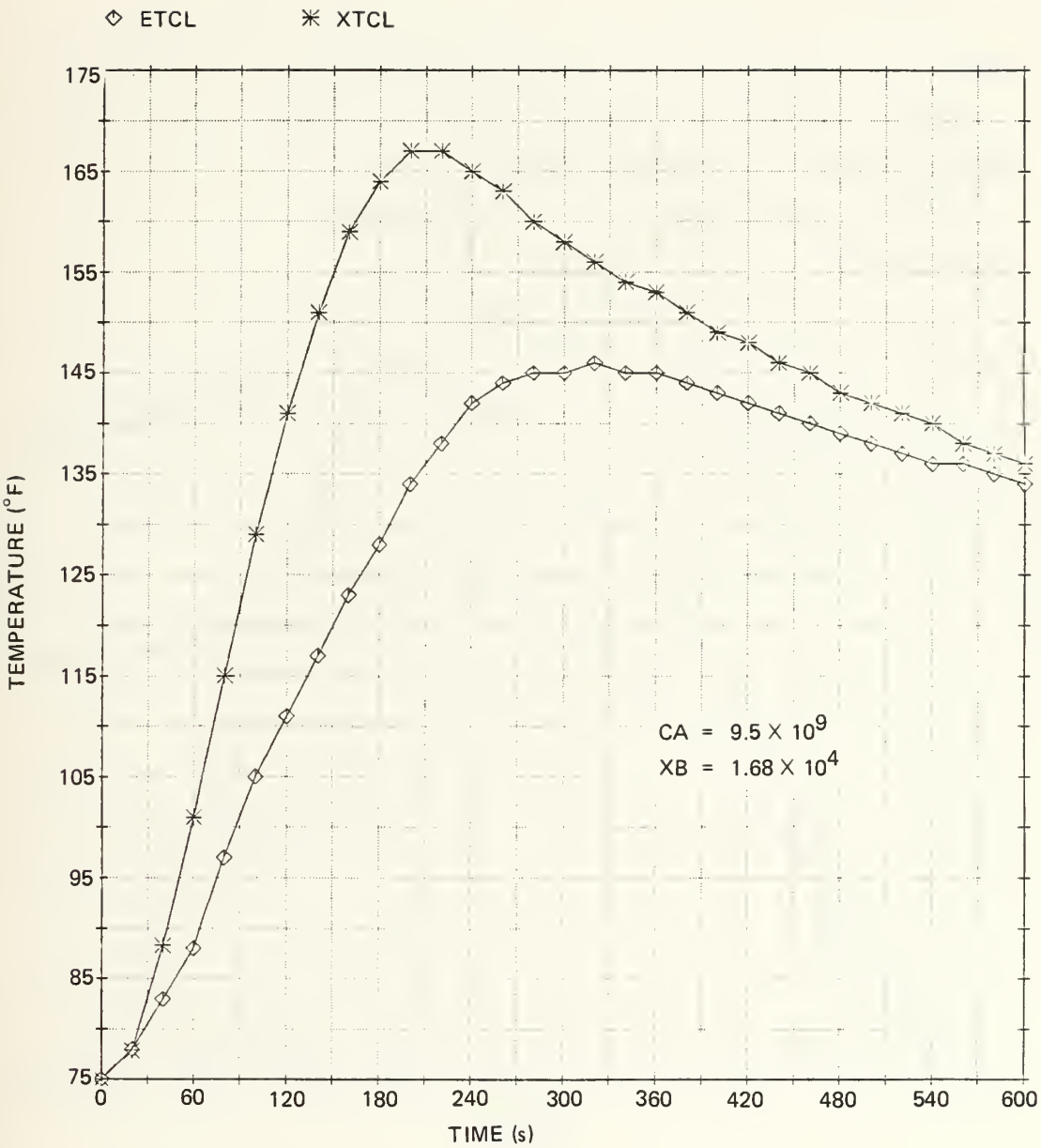


Figure 5.10. Increasing the temperature range of the ablative zone.

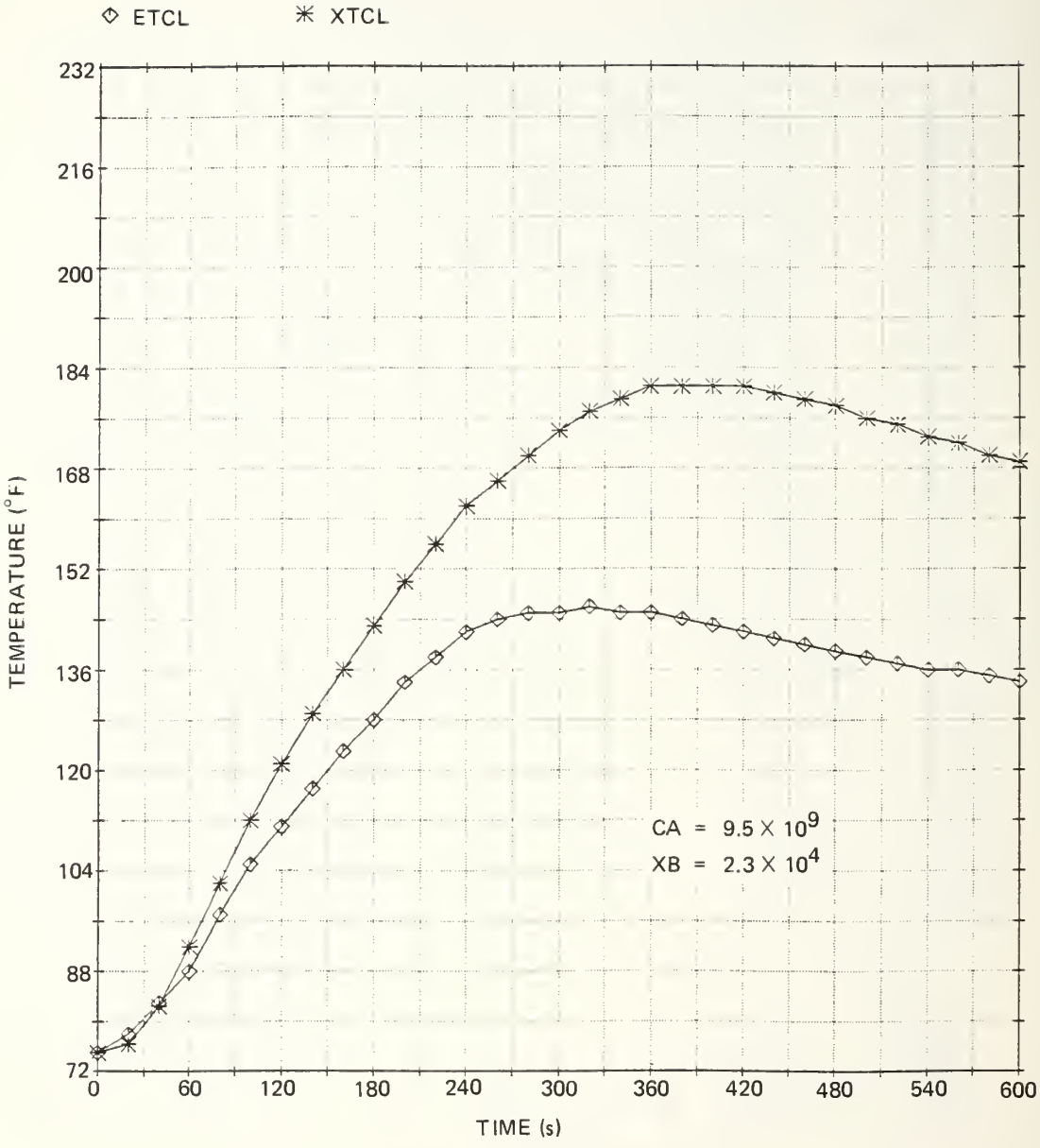


Figure 5.11. Increasing the activation energy, XB.

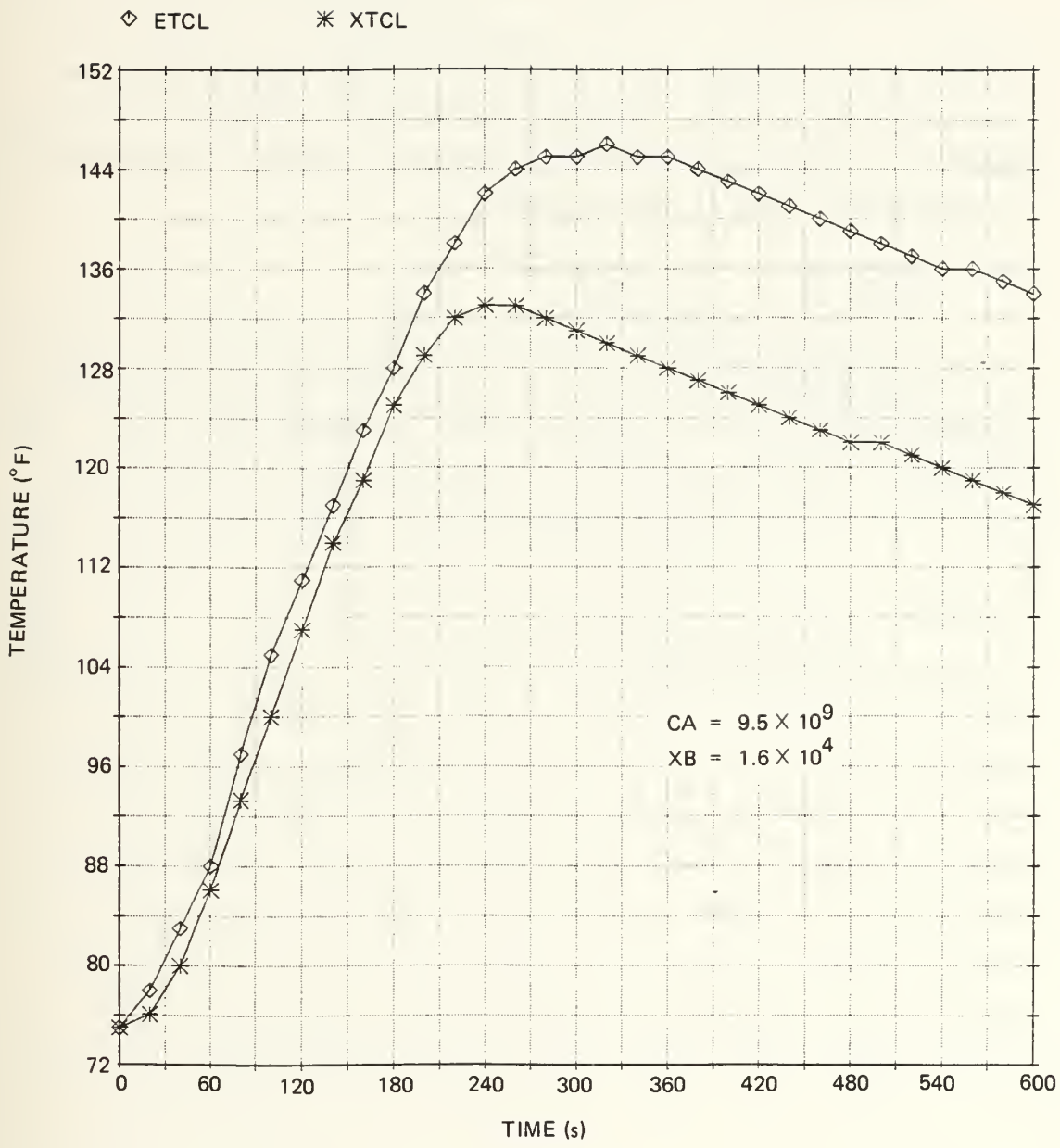


Figure 5.12. Decreasing the activation energy, XB.

5.4.6 Increase CA

Increasing CA has the same effect as decreasing XB, but to a lesser degree. In Figure 5.13, CA is increased from 9.5×10^{9} to 2×10^{10}. The shape of the experimental curve, ETCL, and the computer-predicted curve, XTCL, is the same. Increasing CA has merely reduced the relative temperatures especially in the region where the material is cooling down. The conductivity model is seen in Figure 5.4.

5.4.7 Decrease CA

The effect of decreasing CA can be seen in Figure 5.14. Here CA was increased ten times to 9.5×10^{10}. As in the case of increasing CA, the shape of the curve also closely matches the experimental curve. The difference is that the decrease in CA has increased the thermocouple temperatures. Again the conductivity model for this run is seen in Figure 5.4.

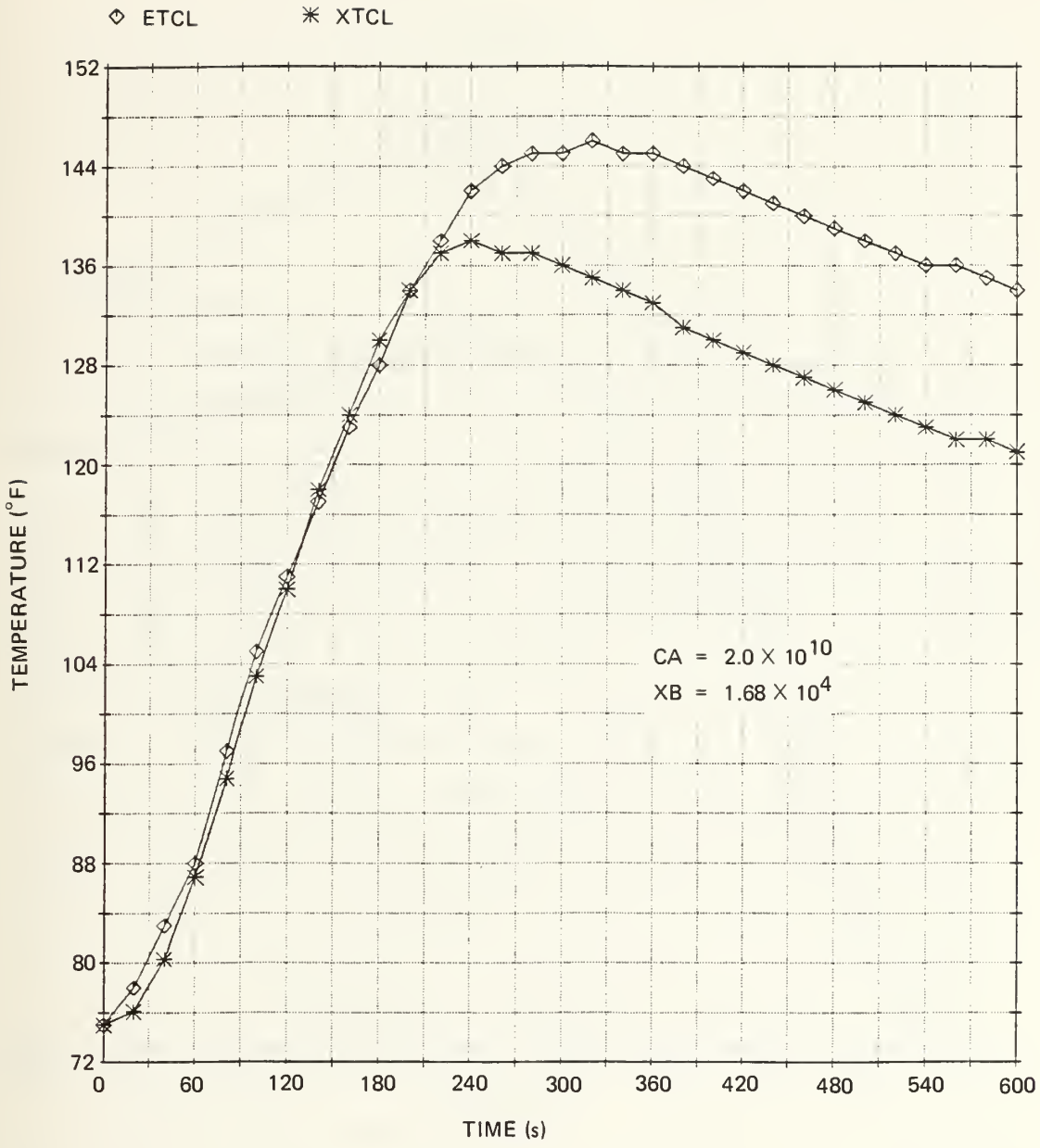


Figure 5.13. Increasing the frequency factor, CA.

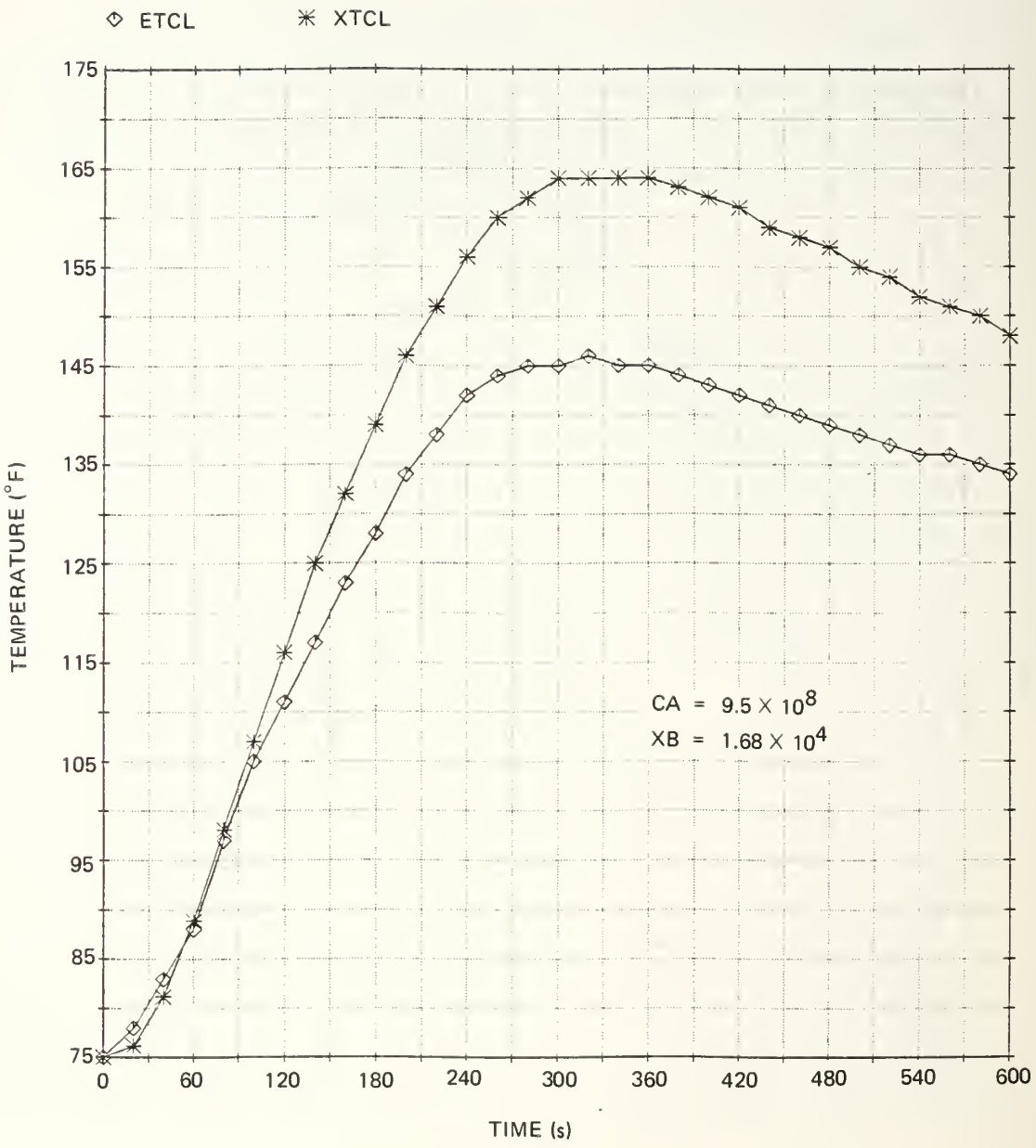


Figure 5.14. Decreasing the frequency factor, CA.

CHAPTER 6

MODEL TESTING

6.1 Introduction

By altering the frequency factor, the activation energy, and the conductivity of the material, this author was able to adjust the computer model to almost perfectly match the experimental results at one thermocouple location for one burn condition. The correlation between the selected model and the experiment is seen again in Figure 5.3. Because the necessary adjustments to the computer model involved altering the values of variables for which exact information was unavailable, the question exists as to whether or not the selected model can as accurately predict the thermal response of different tests on the material. In order to answer this question, several additional runs of the selected model have been executed. These additional tests of the model were performed for cases in which comparative data was available from Lt. Marques's experiments. The next several sections will show that the selected model is not as accurate in predicting the thermal response of Firex 2373 under conditions of different specimen size, different heat flux duration, and at different thermocouple locations as it was in predicting the temperature response at the 0.25-inch thermocouple of a 2-inch slug exposed to a 200-second burn. However, the model predictions are reasonably close to experimental data. In view of all the adjustments that were required to select the model, the following results are not surprising.

6.2 Computer Predictions at a Different Thermocouple Location

This author decided to compare the computer predictions of the temperature response at a thermocouple location of 0.50 inch from the slug surface. The experimental data for this comparison came from the same 2-inch slug of Firex exposed to a 200-second burn. Figure 6.1 shows the results of this comparison. Clearly the match is not as good at this location, and although the curves have similar shapes, the computer-predicted temperatures are lower. Incidentally, the shape of the curves indicate that at this location only conduction is occurring and none of the material is ablating. The mismatch in temperatures is not favorable from a design standpoint because the computer predictions are less conservative. In spite of the mismatch, the maximum temperature difference at any time is only 16°F.

The reasons for the differences in the temperature values could be that the intumesced conductivity is over-modeled, that too much heat is allowed to reradiate from the surface by improper emissivity inputs, or that the boundary condition which exists at the backface of the test slug is improperly specified in the program. The computer program simulates an adiabatic boundary condition at the slug backface, and although Lt. Marques's experimental apparatus strove to provide this same boundary condition, this author believes that there could actually be some heat flowing into the slug as a result of the rise in environmental temperature which occurs in the burning hood during a 200-second burn.

6.3 Computer Predictions for a Different Burn Time

Figure 6.2 shows the comparison of thermocouple temperatures at 0.25 inch for a 45-second burn of a 2-inch slug of Firex. Although these results compare more favorably than those shown in Figure 6.1, again, the computer-predicted temperatures are slightly lower than those observed experimentally. In this case the maximum temperature difference is 13°F. The reasons for this mismatch are the same ones as those noted in

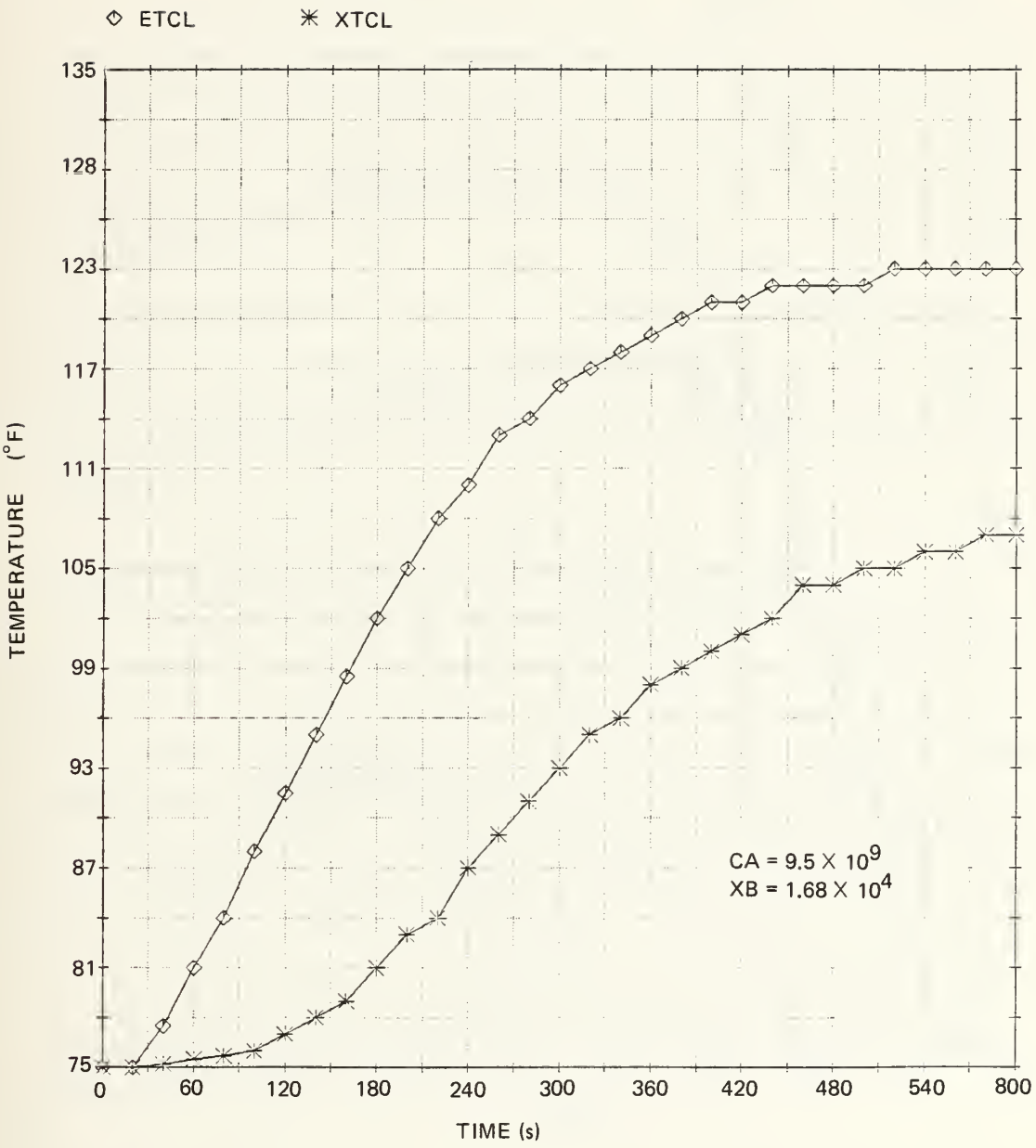


Figure 6.1. Test of selected model. 200-second burn on 2-inch slug of Firex 2373. Experimental, ETCL, and computer predicted, XTCL, thermocouple locations are 0.50 inch from the slug surface.

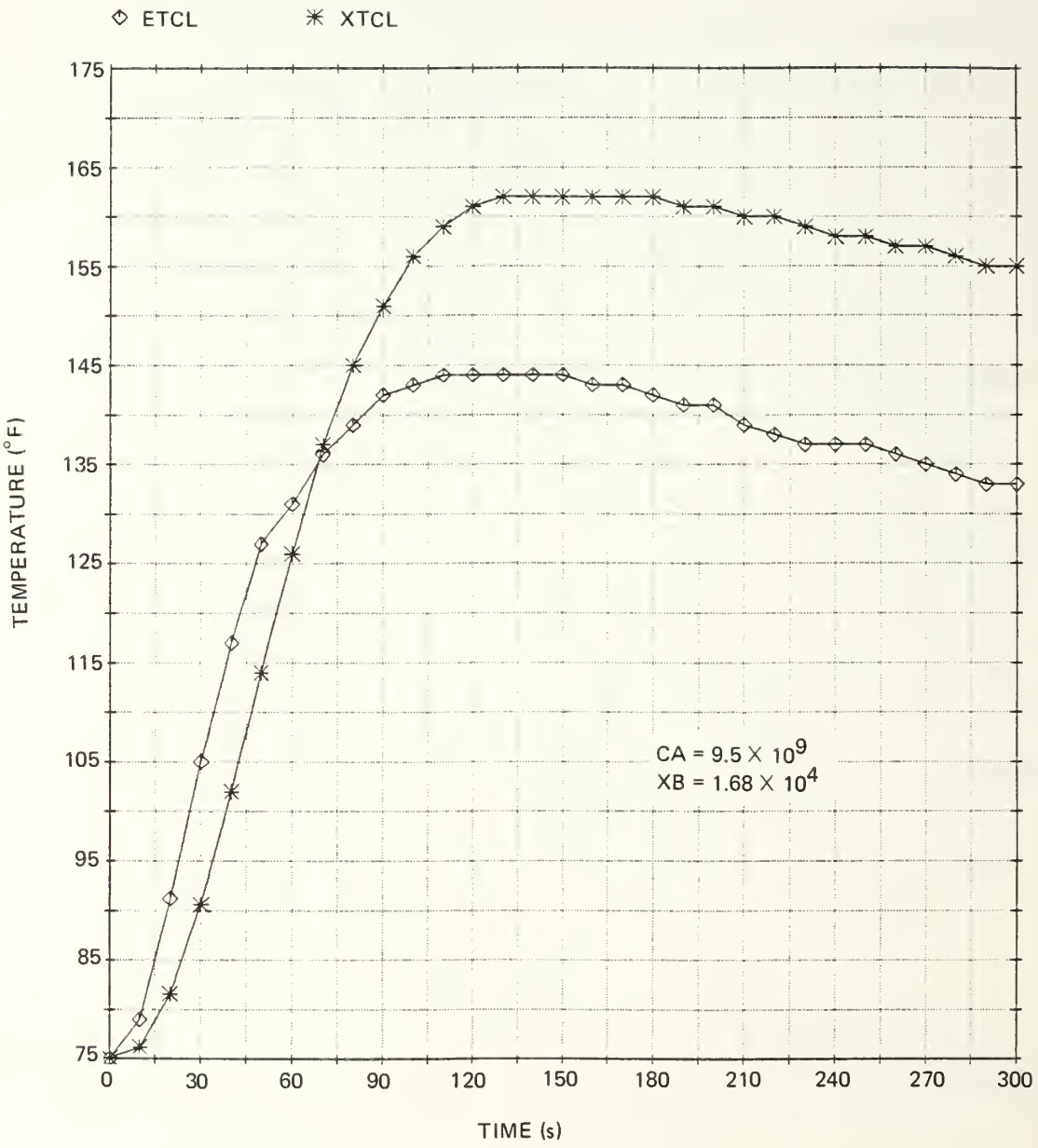


Figure 6.2. Test of selected model. 45-second burn on a 2-inch slug of Firex 2373. Experimental, ETCL, and computer predicted, XTCL, thermocouple locations are 0.25 inch from the slug surface.

the previous section. One point to note is that the 45-second burn equates to an integrated heat flux of 450 Btu/ft^2, while the 200-second burn is an integrated heat flux of 200 Btu/ft^2. In LCDR Leary's work, he discusses that, in general, intumescent ablators are more effective in situations where the integrated heat fluxes are less than 1000 Btu/ft^2 and charring ablators are more effective above 1000 Btu/ft^2. In light of this observation, perhaps the computer model of Firex should have been matched on the 45-second burn, but this author feels the results of the longer 200-second burn are more reliable. With a little experimentation, the author discovered that if XB is increased to 19,000, the computer predictions are much closer to the experimental data; but then the model doesn't match as well for the case of the 200-second burn. Again, the shape of these curves indicates that the 0.25-inch thermocouple is in a conduction only zone.

6.4 Computer Predictions for a Different Size Specimen

The temperature data from the tests performed to rank candidate ablative materials to replace Firex was for a thin 0.1875-inch wafer of Firex which was burned for 45 seconds. The data Lt. Marques recorded was for a thermocouple attached to an aluminum backing plate which placed the thermocouple 0.25 inch from the wafer surface. Because the computer program does not allow the placement of thermocouples in any backup material, the closest any computer thermocouple could be placed was at a distance of 0.1875 inch from the wafer surface. The results of this comparison are seen in Figure 6.3. The shape of the curves is well matched, and as expected, the closer thermocouple, the one at 0.1875 inch, has the highter temperatures. It appears that if bith thermocouples were at the same location, the match may actually be quite good. Not too many conclusions can be drawn from this comparison, except to say that the selected Firex model appears to be fairly good at predicting the temperature responses of different size specimens.

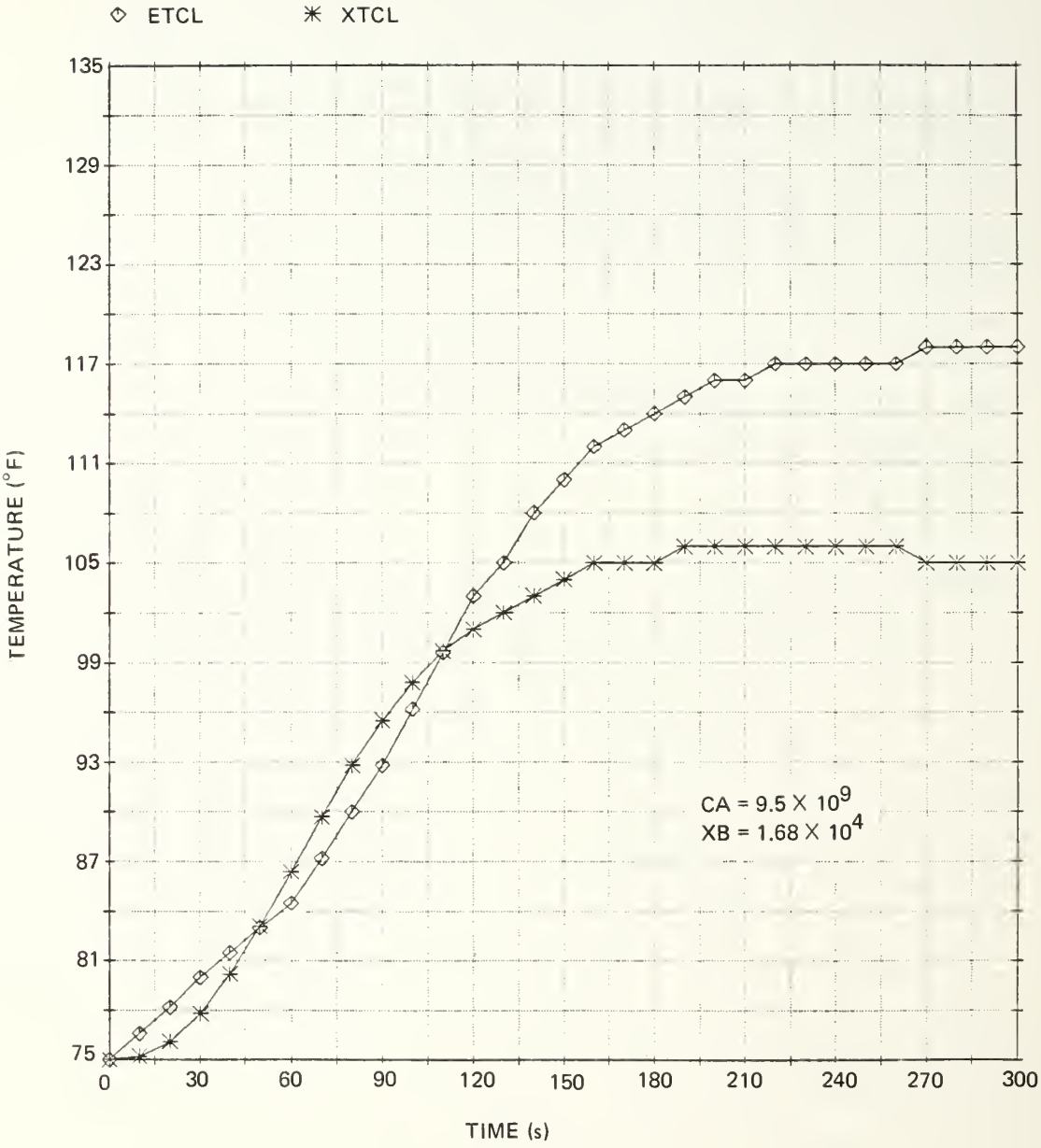


Figure 6.3. Test of selected model. 45-second burn on a 0.1875-inch wafer of Firex 2373. Experimental, ETCL, thermocouple location is 0.25 inches from the wafer surface. Computer predicted, XTCL, thermocouple location is 0.1875 inch from the wafer surface.

CHAPTER 7

NAVAL APPLICATIONS OF INTUMESCENT ABLATIVE MATERIALS

7.1 Introduction

Ablative materials have been primarily used in man's pursuit of space exploration, but now these materials are beginning to find applications in the field of naval engineering and many other conservative disciplines. Intumescent ablators are being used, in fact, in several types of applications onboard combatant ships of the U.S. Navy. They are being used primarily as protective coatings to retard the spread of fire, to insulate munitions from the generated heat of fires, and to protect structural members of a ship from the flame damage of ship-launched missiles. The purpose of this chapter is to summarize the use of intumescent coatings on board U.S. Navy ships. Much of the information for this chapter comes from the work of my colleague, LCDR James Leary, whose thesis, Reference (2), entitled Characteristics of Various Types of Ablative Materials with Associated Naval Applications, covers this entire topic in much more detail.

7.2 Intumescent Ablative Materials as Fire-Retardant Coatings

7.2.1 Introduction

Shipboard fires have continually presented hazardous circumstances for a ship and her crew because of their ability to quickly spread out of control and because of the intense heat generated which can self-ignite stored munitions. Shipboard fires are even more severe on modern combatant vessels which carry large amounts of weapons and large loads of

highly volatile fuel. Also, as demonstrated in the Falkland Islands War, many of the alloys currently used in combatant ships burn at such high temperatures when ignited that conventional fire-fighting techniques are largely inadequate in controlling these metal fires.

Some of the most recent tragic fires experienced by U.S. Navy ships have been the 1967 flight deck fire on the U.S.S. Forrestal, the 1969 flight deck fire on the U.S.S. Enterprise, and the fires resulting from the 1975 collision between the U.S.S. Kennedy and U.S.S. Belknap. All of these fires involved loss of life and significant degradation in combat readiness. The worst case was the U.S.S. Belknap which spent three years being repaired from the collision and fire damage she incurred. In most of these fires, the fire-fighting teams had insufficient time to control the fires in their early stages, and in all of them, the self-ignition (cook-off) of ammunition was directly responsible for increasing both the fire's severity and the complexity of the fire-fighting solution.

7.2.2 Research Effort

The result of the first two aircraft carrier fires was a concentrated research effort into finding a coating which could be applied to munitions to decrease the tendency of the munitions to self-ignite. Testing conducted at the Naval Weapons Center, China Lake, California showed that when different munitions and missile warheads were exposed to simulated aircraft carrier deck fires, the unprotected munitions and warheads exploded within three minutes of exposure to the fire. In comparison, fire-fighting teams today normally require at least five minutes to organize, set boundaries, and bring a fire under control.

Testing of various ablative coatings at China Lake determined that an intumescent ablative coating when applied to munitions could increase the average time for self-ignition to at least 8.5 minutes.[21] Interestingly enough, the intumescent coating selected from these tests was

Firex, the same material currently used to insulate the inertial measurement unit discussed in the preface of this thesis. To coat munitions, Firex is applied with normal spray equipment and not molded as it is in the IMU application. The beneficial fire-retardant effects of Firex proved to be so good that it has been used to coat the pipes and valves of the aviation fuel handling systems on aircraft carriers. It is also being used on carriers to coat selected bulkheads in areas where an aviation fuel fire might occur. The use of Firex was practically tested in the U.S.S. Kennedy - U.S.S. Belknap collision. The U.S.S. Kennedy, which had the protective coating, was able to quickly contain its fire and continue along on its assigned mission. The U.S.S. Belknap, on the other hand, which did not have the coating, suffered major damage as her fire-fighting crews were not afforded the extra time the coating provides to control the fire.

Basic research into shipboard fires is being conducted under a Navy contract by The Center for Fire Research at the National Engineering Laboratory, National Bureau of Standards. In their work, the center has developed the concept of flashover. Flashover is defined as the condition when thermal radiation levels at a bulkhead become high enough to simultaneously ignite combustible materials within a compartment.[22] The condition of flashover equates to a bulkhead temperature of approximately 1200°F and a radiant heat flux on the order of 6 Btu/ft^2-s. By using intumescent paints on bulkheads, the center has been able to demonstrate that the flashover condition can be delayed substantially when the coated bulkhead is exposed to a fire. In some cases the painted bulkheads do not experience the flashover condition until ten minutes after the bulkhead becomes hot, thus allowing shipboard fire-fighting teams the necessary time to extinguish a fire. For results on flashover testing of specific paints see Table 12 of Reference (2).

An additional benefit to using intumescent coatings on selected ship bulkheads is that they greatly reduce the overall generation of

carbon monoxide, hydrogen cyanide, hydrogen chloride and smoke in compartment fires.[23] A disadvantage to these coatings is that they do present a slight weight penalty. This is because in order to be fully effective, an intumescent coating must be applied to a thickness of 0.025 cm, while normal decorative paint is only applied to a thickness of approximately 0.010 cm. The density of an intumescent coating and a decorative paint are about the same and the weight penalty in using an intumescent coating instead of a paint is about 0.03 lb/ft^2. As noted by LCDR Leary, this weight penalty appears small in considering the enormous benefits an intumescent coating provides. However, this does not mean that every bulkhead in a ship should be coated with an intumescent paint.

7.2.3 Current and Future Uses

As mentioned previously, intumescent coatings are used in protecting all heat-sensitive munitions. They are also used in all aircraft carriers in the aviation fuel systems, as well as on selected bulkheads. Submarines use them as both a thermal and acoustic insulation in the interior of their hulls. A new design mine countermeasures ship (MCM) which has a wooden hull uses an intumescent paint in the entire engineroom.

Future uses of fire-retardant intumescent coatings include their use in the offshore platform industry to protect members of the platform from structural damage in the case of platform fires. Hopefully, U.S. Navy surface combatant ships other than aircraft carriers will begin to incorporate intumescent coating in areas where exposure to fuel fires is highly possible.

7.3 Intumescent Ablative Materials Used to Protect Shipboard Structures from Missile Exhaust Gases

The advent of missile-launched weapons has made it necessary to specially protect those areas of the ship which are exposed to the hot exhaust gases from launched missiles. The problems associated with exposure to these hot gases are: thermal expansion causing possible failure

of missile launching mechanisms, thermal fatigue of the heated hull structure, and unwanted heat transfer through decks and bulkheads to various spaces in the ship. Ablative coatings, particularly intumescent coatings, have proven successful in providing protection from the hot missile exhaust gases onboard U.S. Navy ships.

A major consideration in picking an ablator for this shipboard application, aside from its insulative capability, has been its ability to be applied via troweling or its trowelability. This is a concern because any damage to a missile ablative system must be repairable at sea. Also note that, in general, a ship is required to apply a new ablative coating after firing its entire magazine. Thermal testing of candidate materials to be used on ships was performed under the responsibility of the Naval Surface Weapons Center. The results of the test indicated that an intumescent ablator, Flexfram 605, was the best material. The integrated heat flux used in the tests was less than 1000 Btu/ft^2 which is within the normal range of an intumescent ablator.[24] As a result of these tests, Flexfram 605 has become the standard ablative coating for use on conventional "above main deck" shipboard missile launchers.

New launcher systems are under development which will allow a ship the capability to ripple-fire several missiles at a rapid pace. The heat load involved in this type of operation is much too high to be handled by an intumescent ablator. Therefore, different types of ablators are being examined to provide protection at these higher heat loads. Although subliming ablators (carbon tiles) looked promising, replaceable charring ablative tiles have been selected for use in the new vertical launch system (VLS). These particular tiles can be easily replaced by the ship's crew when it becomes necessary.

7.4 Computer Modeling

Ultimately, the selection of any shipboard ablative protection system will depend on the results of tests which are designed to simulate

the exact thermal environment the system will be exposed to. However, a computer model like the one presented in this thesis can serve as a useful tool in quickly screening candidate materials and determining which ones should be later tested. Also once a material is selected, a computer model of the material is extremely helpful in predicting the effects on any future design changes and in predicting the material response long after the testing facilities are dismantled. Perhaps in the not too distant future a model of the ablative protection system could be included onboard a ship central computer to be used in damage control calculations.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The charring ablation computer program, STAB II, can be successfully modified to model the thermal response of an intumescent ablator. Although this thesis only modeled one intumescent ablator, Firex 2373, the information presented in this work should make the modeling of any other intumescent ablator a straightforward process. In order to use the STAB II program to model an intumescent ablator, careful selection of the material's conductivity values is required. As previously stated, since STAB II does not incorporate an algorithm to account for the surface swelling of an intumescent ablator, the inputted conductivity model attempts to compensate for this deficiency. Thus, the conductivity values necessary to make the model predict experimental results are really "effective" conductivity values.

The results presented in Chapters 5 and 6 demonstrate that the selected model for Firex 2373 is extremely accurate in predicting the temperature response of Firex at one particular thermocouple location. This model is not, however, as accurate in predicting the temperature responses at other thermocouple locations. Also, the model is seen to be moderately affected by the size of the test specimen inserted into the program. Several thoughts on these inaccuracies are included in the following paragraph.

The values selected for Arrhenius equation coefficients may, in fact, be incorrect; although the literature has suggested that the chosen

values were clearly within reason. However, obtaining the exact values of these coefficients is important, because even small changes in either the activation energy or the frequency factor can produce significant changes to the model's predictions. Another problem may be that the conductivity values used to account for the intumescence may be over modeled. In other words, the "effective" conductivity of the intumesced virgin material may really be too low. Selecting the proper backup materials for the computer program is still another problem as is modeling the boundary condition at the backside of each test specimen. Experimentally, it is very difficult to ensure that only one dimensional heat flow is occurring in the test specimen and it is nearly impossible to perfectly insulate the backside of the test specimen. Lastly, since only a few tests could be run on Firex 2373, normal experimental variations in the data made it very hard to select the temperature values to be used for the computer matching.

Ideally, the chosen model can predict, with the same degree of accuracy, the temperature response of the material at any thermocouple location. Unfortunately, because of the many uncertainties mentioned above, the present model of Firex 2373 is unable to do this. It appears that in using the STAB II program to model Firex and other intumescent ablators, the program will have to be altered separately to predict the thermal response at any specified depth or for any specimen size. The model will, of course, always have to be adjusted to experimental data; but once this is done, the model can serve as a tremendous design tool in predicting the thermal response of the material to different heat flux environments. This author has demonstrated that the STAB II program is relatively simple and inexpensive to run. This makes it an ideal candidate for incorporation into a larger program such as the IMU simulation program currently being used at The Charles Stark Draper Laboratory.

A specific conclusion is that the material, Firex 2373, seems to be quite effective in insulating the inertial measurement unit from the exposure to a uniform heat flux of 10 Btu/ft^2-s for periods of 45 and

200 seconds. Intumescent ablators are, in general, extremely effective insulators in low heat flux applications. These types of ablators are being used in several industrial applications and in an addendum chapter to this thesis, Chapter 7, the naval applications of intumescent ablators are described. Intumescent ablators have been proven to be very successful in insulating strategic parts of a ship from the heat generated by shipboard fires. Chapter 7 argues for the use of more intumescent ablators onboard U.S. Navy ships, particularly for use on board small combatants. One final note is that from the results of the three intumescent ablators tested by Lt. Marques, it appears that the inverse of the virgin diffusivity may be a way to rank the effectiveness of an intumescent ablator. That is, the lower an intumescent's diffusivity, the more effectively it insulates a piece of equipment from low heat fluxes.

8.2 Recommendations

The following recommendations are made to improve the use of the STAB II program and to enhance the results of this thesis:

(1) Perform more conductivity testing on Firex 2373, particularly of an intumesced piece. Also, the char of Firex should be tested for conductivity even though this may prove to be quite difficult.

(2) Perform thermogravimetric, TGA, tests on Firex to get better bounds on the values of the frequency factor and the activation energy. This testing can be performed at Draper Laboratory. Knowing these Arrhenius coefficients could really change the procedures used to adjust the computer model.

(3) In order to gain a better understanding of the model, more work should be done in matching experimental data at different thermocouple locations. Also more testing of Firex 2373 should be performed to provide a better data base.

(4) More computer experimentation is necessary to determine the effects various backup materials and different boundary conditions have on the computer predictions.

(5) More intumescent ablators should be experimentally tested and then the computer program should be used to model these different intumescents. The results of this effort may produce trends from which stronger conclusions may be drawn about intumescent ablators. As postulated by Professor Warren M. Rosenhow, perhaps the conductivity models of all intumescent ablators will have the same shapes. This result would be significant.

(6) The surface energy balance in the program needs to be corrected to prevent surface temperature oscillations. This can be done by either inserting a separate loop in the program which would perform an iterative energy balance at the surface or by performing a Newton-Raphson integration at the surface. Note that Dr. Curry felt the later option could be part of a doctoral thesis.

(7) The STAB II program should be adjusted to allow more than one case to be executed on each run of the program. The program has this capability at NASA/Houston and this author feels the problem is in the subroutine RESET. This subroutine was not included in the tape and Dr. Curry felt it was not important but it may be very important for running multiple cases.

(8) It would be very beneficial to add an internal plotting routine to the program which could be run when desired. The DISPLAY plotting routine on the CSDL computer system could be used for this.

(9) Ultimately, a new computer program or subroutine needs to be devised to allow for the surface swelling of an

intumescent ablator. This task may prove difficult, but researchers Henderson, Moore, and Tant are presently working on such a program at the Naval Surface Weapon Center, Dahlgren, Virginia.

APPENDIX A

SUBROUTINE SUMMARY

The purpose of this Appendix is to briefly describe the function of each subroutine in the STAB II program. The information for this Appendix is largely from Reference (8). More detailed information concerning the specific calculations performed in each of the subroutines is available in Chapter 6 of this reference.

1. MAIN - The main routine is the program driver and is described by the logic diagram, Appendix F.

2. SUBROUTINE ABLATE - This subroutine determines the pyrolysis gas generation rate from the ablating nodes.

3. SUBROUTINE ABL2 - This subroutine determines the pyrolysis gas generation rate when nodal subdivision is used. The equations are the same as in ABLATE except that the calculations are for each subnode instead of each node. The subnode contribution is summed and values for each node are returned.

4. SUBROUTINE ALLMOL - This subroutine calculates local density and local temperature as a function of entropy and local enthalpy. The routines used are MOLP, MOLR, MOLT, and MOLA.

5. SUBROUTINE ATMOS - ATMOS uses subroutines ATMOS3 and ATSEAS to calculate the free stream temperature, pressure, and density from one of the ten possible atmospheric models as a function of altitude.

6. SUBROUTINE ATMOS3 - This subroutine calculates the free stream pressure, density, and temperature for the 1962 standard atmospheric model.

7. SUBROUTINE ATSEAS - ATSEAS calculates the free stream pressure, density, and temperature for the nine nonstandard atmospheric models. Note in the application of STAB II for this thesis, this subroutine was never called since the 1962 standard atmospheric model was always used. BDAT is called by ATSEAS.

8. SUBROUTINE BDAT - This subroutine loads the desired atmospheric table when called by ATSEAS.

9. SUBROUTINE BET - The temperature at each thermocouple location is determined by a third-degree Lagrangian polynomial curve fit of the temperature profile. BET calls DISCT3, which in turn calls DISSER and LAGRAN.

10. SUBROUTINE COEFF - The calculation of the tri-diagonal coefficient matrix used in the temperature solution is performed by COEFF. This subroutine calls PROP for the thermophysical properties of the ablator.

11. SUBROUTINE COKE - The mass flow reduction rate due to coking is calculated in this routine. This subroutine was never really called in the application of the program to this thesis.

12. SUBROUTINE COMMOL - This is a specialized double interpolation routine used by the Mollier Fits subroutines.

13. SUBROUTINE DISCOT - DISCOT determines the viscosity of air as a function of local temperature. This routine calls UNS, DISSER, and LAGRAN.

14. SUBROUTINE DISCT3 - This subroutine is used as a driver to call DISSER and LAGRAN.

15. SUBROUTINE DISSER - This subroutine determines the array points to be used by LAGRAN for polynomial interpolation.

16. SUBROUTINE DOUBLE - DOUBLE is used by the table input package to do the interpolation for functions of two variables.

17. SUBROUTINE DPDX - DPDX calculates the internal pressure distribution. For this thesis, this option was not used; therefore, the subroutine was not called.

18. SUBROUTINE FINDS - This subroutine returns the total pressure, total enthalpy, and entropy as a function of free stream temperature, density, pressure, and velocity. FINDS calls MOLS and MOLR.

19. SUBROUTINE INDATA - This subroutine initializes many variables and reads the NAMELIST variables.

20. SUBROUTINE INWRIT - INWRIT prints the input data and local properties.

21. SUBROUTINE ISOTHM - Linear interpolation is used to calculate the isotherm and density ratio penetration depths.

22. SUBROUTINE LAGRAN - This subroutine performs a Lagrange polynomial curve fit.

23. SUBROUTINE MAINDA - This is really not a subroutine but a block data statement which assigns values for most of the variables associated with the backup materials. This data statement also assigns the conductivity and specific heat values for both the virgin material and the char. Originally, this data was included in the MAIN member of the program, but in order to satisfy VS FORTRAN requirements, a separate block data member called MAINDA was created.

24. SUBROUTINE MOLA - Mollier Fits subroutine that provides the local speed of sound. MOLA calls TESTH and COMMOL.

25. SUBROUTINE MOLH - Local enthalpy as a function of temperature and local pressure is determined by this Mollier Fits subroutine. MOLH calls COMMOL.

26. SUBROUTINE MOLP - This Mollier Fits subroutine returns the total pressure. MOLP calls TESTH and COMMOL.

27. SUBROUTINE MOLR - This Mollier Fits subroutine determines the local density. MOLR calls TESTH and COMMOL.

28. SUBROUTINE MOLS - MOLS provides the local entropy. This Mollier Fits subroutine calls TESTH and COMMOL.

29. SUBROUTINE MOLT - Local temperature is returned by this Mollier Fits subroutine. MOLT calls TESTH and COMMOL.

30. SUBROUTINE OXIDAT - This subroutine calculates the heat generated due to exothermic oxidation of the char surface. It is assumed that oxygen and carbon react to form carbon monoxide only. The heat fluxes were too low in our application to ever have oxidation of the char.

31. SUBROUTINE PROP - Subroutine PROP is called by COEFF and returns the thermophysical properties of the ablator and backup structure. Linear interpolation is used to obtain the properties of each node. The properties of the ablator are input as constants or as functions of one or two variables, while the backup material properties are input as functions of temperature only.

32. SUBROUTINE RECESS - The char mass removal rate and the surface recession rate due to char removal is determined by RECESS.

33. SUBROUTINE RITE - This subroutine outputs the thermocouple locations and their corresponding temperatures in tabular form.

34. SUBROUTINE SINGLE - This subroutine is used by the table input package to do the interpolation for functions of a single variable.

35. SUBROUTINE SUBL - The surface mass loss rate due to sublimation of carbon is computed by SUBL. In our applications, the surface temperatures were never great enough to cause carbon sublimation.

36. SUBROUTINE SWUFT - SWUFT determines the forward timestep temperatures by solving the system of equations whose coefficient matrix was calculated by COEFF.

37. SUBROUTINE TBKIND - Table input subroutine used to determine the interpolation options and setup the arrays to SINGLE and DOUBLE.

38. SUBROUTINE TBLSET - TBLSET sets the indices used in the table input package.

39. SUBROUTINE TBLST - This subroutine is the table input package driver for storing and writing table data.

40. SUBROUTINE TBLWRT - This subroutine writes the table input data.

41. SUBROUTINE TBLSHUV - TBLSHUV deletes unused tables and realigns needed tables in storage.

42. SUBROUTINE TEMPD - The initial temperature distribution in the ablator and backup structure is provided by TEMPD when an arbitrary distribution is not input. Note an arbitrary distribution was never used in the input for this thesis.

43. SUBROUTINE TESTH - TESTH checks to see if the independent variable exceeds the range of the Mollier tables, which are built into subroutines MOLA, MOLH, MOLP, MOLS, and MOLT.

44. SUBROUTINE TURF - Subroutine TURF calculates the local properties and the turbulent heating factor for each trajectory point.

45. SUBROUTINE UNITRP - This subroutine is a specialized interpolation routine used by the Mollier Fits package.

46. SUBROUTINE UNS - UNS is used by DISCOT to set up index parameters used in the viscosity calculation.

APPENDIX B

NAMELIST VARIABLES

NAMELIST VARIABLES

Symbol	Description	Nominal Value*	Assigned**	Dimension	Comments
ABLC	Specific heat of material at temperature, TABL (Btu/lbm-°R)	0.40	INDATA/ INPUT	(Real)	
ABLK	Thermal conductivity of material at the temperature, TABL (Btu/hr-ft-°R)	0.108	INDATA/ INPUT	(Real)	
ALFAC	Viscous resistance coefficient of charred material, used for internal pressure distribution calculation (ft^{-2})	5.78E9	INDATA	(Real)	Not used because internal pressure distribution never sought
ALFAV	Viscous resistance coefficient of virgin material, used for internal pressure distribution calculation (ft^{-2})	7.15E10	INDATA	(Real)	Not used since internal pressure distribution never sought
ALT	Altitude table corresponding to trajectory time table (ft)	—	INPUT	Real (300)	Must be input but set to zero for each TIME
AOT	Angle-of-attack table corresponding to the trajectory time table. Used in the variable factors calculation, i.e., PLPTX $\leq$ 0. (deg)	—	INPUT	Real (300)	Never input for our application

* The nominal values quoted reflect values for the simulation of FIREX 2373.

** "INDATA/INPUT" indicates that although the nominal value can be assigned in the INDATA subroutine; in order to adjust the model to conform to test results, the value of this parameter was frequently changed and thus, used in the INPUT statement.

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
BETAC	Inertial resistance coefficient of charred material, used for internal pressure distribution calculation (ft^{-1})	1.92E5	INDATA	Real	Not used
BETAV	Inertial resistance coefficient of virgin material, used for internal pressure distribution calculation (ft^{-1})	0.0	INDATA	Real	Not used
BTEST	Flag to determine the mode of heat transfer at the back surface of each backup structure material = 0 Conduction only = 1 Convection only = -1 Radiation only, or radiation and convection	0.,0.,0.	MAINDA	Real (12)	Normally set to 0 for each backup material
CA	Coefficient in Arrhenius equation	9.5E9	INDATA/ INPUT	Real	This value depends on the material and was varied to match laboratory results
CHARC	Specific heat of material at the temperature, TCHAR (Btu/lbm-°R)	0.40	INDATA/ INPUT	Real	—
CHARK	Thermal conductivity of material at the temperature, TCHAR (Btu/h-ft-°R)	0.065	INDATA/ INPUT	Real	—
CPCHR	Specific heat of char material (Btu/lbm-°R)	Table 99997	MAINDA	Real	Assumed values to be the same as for Apollo material

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
CPGAS	Specific heat of pyrolysis gas (Btu/lbm-°R)	0.5	INDATA/ INPUT	Real	Assumed to be the same value as for Apollo material
CPREAC	Specific heat of reaction zone material (Btu/lbm-°R) (See Section 2.4 of User's Manual)	0.		Real	Linear interpolation between char and virgin values
CPVRG	Specific heat of the virgin material (Btu/lbm-°R)	Table 99995	MAINDA	Real	Values in Table are for FIREK 2373
CPX	CPX (1,n) - Specific heat where n is the backup material number (Btu/ lbm-°R)	—	MAINDA	Real (20,12)	At least three backups are required
DELTT	Table of calculation intervals corresponding to TTABLE(s). If DELTT(1) $\leq$ 0, the calculation intervals are generated internally	0.	MAIN	Real (20)	In general, DELTT was specified to provide greater accuracy and not left to internal generation
DHC	Heat of combustion of carbon (Btu/ lbm)	5000.	INDATA	Real	Assumed to be the same as for Apollo material
EMBB	Emissivity of back surface of each backup material	0.65, 0.65, 0.65	MAINDA	Real	—
EMC	Emissivity of charred material		INDATA/ INPUT	Real	—
EMFB	Emissivity of front surface of each backup material	0.65, 0.65, 0.65	MAINDA	Real	—
EMV	Emissivity of virgin material	0.99	INDATA/ INPUT	Real	—

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
FBLOWL	Laminar blowing factor	1.	INDATA	Real	Not pertinent to our application
FBLOWT	Turbulent blowing factor	1.	INDATA	Real	Not pertinent to our application
FCONV	Multiplication factor for convective heat rate	1.	INDATA	Real	Not pertinent to our application
FENV	View factor and emissivity product for radiative heat transfer to environment behind the last backup material	0.	INDATA	Real	—
FRAD	Multiplication factor for radiative heat rate	—	—	Real	Not pertinent to our application
FTEST	Flag to determine the mode of heat transfer at the front surface of each backup structure material = 0 Conduction only = 1 Convection only = -1 Radiation only, or radiation and convection	0.,0.,0.	MAINDA	Real (12)	Normally set to 0 for each backup material
FV	View factor from ablator surface	1.	INDATA	Real	—
GAPX	Width of gap between adjacent materials (in.)	0.,0.,0.	MAINDA	Real (12)	—

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
H	Film coefficient between adjacent materials (Btu/h-ft^2-°R)	0.,0.,0.	MAINDA	Real (12)	No convection between backup materials
HENV	Film coefficient between outside surface of the last backup material and environment (Btu/h-ft^2-°R)	0.	INDATA	Real	No convection
HSUB	Heat of sublimation of carbon (Btu/lb)	12000.		Real	Assumed to be the same
HV	Heat of degradation of virgin material (Btu/lb)	2000.	INDATA/ INPUT	Real	Depends on material and hard to accurately determine
HX	Enthalpy table (Btu/lb)	Table	MAINDA	Real (50)	Assumed to be the same, but does not enter into computations for our application
H300	Enthalpy of air at 300K (Btu/lb)	129.05	INDATA	Real	Assumed to be the same but does not enter into computations for our application
IPRC	Table of print intervals corresponding to TTABLE (no. of timesteps per print) if DELTT(1) $\leq$ 0., IPRC is calculated internally	—	INPUT	Integer	IPRC * DELTT = Print Interval (s)
IPRESS	= 1 Internal pressure distribution calculated $\neq$ 1 Internal pressure distribution not calculated	0	INDATA	Integer	Never had internal pressure distribution calculated
ITHIN	= 1 Standard atmosphere	1	INDATA	Integer	Only a factor for reentry problems

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
MMM	Number of node subdivisions for pyrolysis gas generation rate calculation Restrictions: (1) MMM must be an even integer $\leq$ 20 (2) NP * MMM $\leq$ 500	6	INDATA/ INPUT	Integer	Usually set equal to 2
NCPB	NCPB(m) - Number of entries in specific heat table, CPX(1,m) (20 maximum)	3,3,3	MAINDA	Integer	—
NHP	Number of entries in the enthalpy table, HX (50 maximum)	42	INDATA	Integer	—
NKPB	Number of entries in XK(1,m) table (20 maximum)	6,6,6	MAINDA	Integer	—
NMB	Number of materials in backup structure (12 maximum)	3	INDATA/ INPUT	Integer	Minimum of 3 required
NP	Number of nodes in virgin material Restrictions: (1) NP $\leq$ 50 (2) NP * MMM $\leq$ 500	—	INPUT	Integer	Critical input item
NPTT	Number of entries in TTABLE (20 maximum) Calculated internally if DELTT (1) $\leq$ 0.	—	INPUT	Integer	See TTABLE

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
NREAD	= 0 Trajectory in NAMELIST format	0	INDATA	Integer	—
NREC	Number of entries in surface recession table, SR (50 maximum)	3	INDATA	Integer	—
NTRAPT	Number of trajectory points	—	INPUT	Integer	—
NTURBT	= 0 Laminar case ≠ 0 Turbulent case	1	INDATA	Integer	Not pertinent to our cases
NXTCL	Number of thermocouple locations (15 maximum)	—	INPUT	Integer	Not allowed to be in backup materials
PHI	Body-point reference angle. Used for variable factors calculation, i.e., PLPTX $\leq$ 0.	—	INPUT	Real	Not used in our applications
PLPTX	Ratio of local pressure to total pressure. Also the indicator for constant or variable factors run PLPTX > 0. Value is used as constant pressure ratio, and the factors FCONV, FRAD, and WX must be input PLPTX $\leq$ 0. Factors will be calculated for each trajectory point. PHI, SOVR, and AOT must be input	1.	INDATA	Real	Always used PLPTX > 0
QCONC	Reference convective heating rates corresponding to trajectory time table (Btu/ft^2-s)	—	INPUT	Real (300)	Normally set to 0 - no convective heating in our application

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
QLOSS	Boundary condition between last node of backup structure and cabin environment = 0. No heat exchange ≠ 0. Heat exchange	0.	INDATA	Real	Only a small change noticed when QLOSS set to ≠ 0
QRAD	Reference radiative heating rates corresponding to the trajectory time table (Btu/ft^2-s) (If QCONC(1) < 0., QRAD is the surface temperature (°F))	—	INPUT	Real	—
RHOBX	RHOBX(n) - Density of nth backup structure material (lb/ft^3)	SEE MAINDA	MAINDA	Real (12)	—
RHOC	Density of charred material (lb/ft^3)	20.	INDATA	Real	Assumed to be the same value as for Apollo material
RHOS	Density of receding surface without coking	16.	INDATA	Real	Assumed to be the same value as for Apollo material. Since surface recession was set to 0 it never entered into calculations
RTR	Transitional Reynolds number for turbulence	80000.	INDATA	Real	—
SHAPEF	Shape factor for turbulent heating conditions	0.05532	INDATA	Real	Not pertinent to our applications
SN	Reaction order for Arrhenius equation	1.	INDATA	Real	Left at 1.

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
SOVR	S/R, Body-point displacement from center of heat shield	—	—	Real	Not pertinent to our applications
SR	Surface recession table (in./s)	See MAINDA	MAINDA	Real (50)	All values set to 0.
TABL	Temperature at which pyrolysis begins (°R)	660.	INDATA/ INPUT	Real	Difficult to accurately determine experimentally
TCHAR	Char temperature (°R)	860.	INDATA/ INPUT	Real	Difficult to accurately determine experimentally
TCOFF	Table of the times of thermocouple burnout (s)	2.0E6	INDATA	Real	Never used
TCP	TCP(1,m) - Temperature values for the specific heat table, CPX(1,m) (°R)	See MAINDA	MAINDA	Real (20,12)	—
TEMDI	TEMDI(n) Initial temperature of the nth node for TEST2 < 0., backup structure included (°R)	—	—	Real (200)	TEST2 < 0 never used
TEMPI	Initial temperature of ablation material and backup structure for TEST2 = 0. (°R)	535.	INDATA/ INPUT	Real	—
TENV	Temperature of interior cabin environment (°R)	535.	INDATA/ INPUT	Real	—

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
TEST2	Determine the proper test specimen initial temperature distribution = 0. Constant (see TEMPI) = > 0. Linear (see TXO) = < 0. Arbitrary (see TEMDI)	0.	INDATA	Real	Always used 0.
TFACT	Parameter for determining the print interval when TTABLE is not input TFACT * 50 = seconds of run time per print	1.	INDATA	Real	When conditions allow a larger DELTT this factor can still be used to give you smaller print intervals
TIME	Time table for heating inputs (s)	—	INPUT	Real	—
TINT	Initial time for calculations (s)	0.	INDATA	Real	—
TLIM	Final time for calculations (s)	—	INPUT	Real	—
TREAD	TREAD = 1. must be input for each case that has table input (See Section 2.4 of STABII User's Manual)	0.	INDATA	Real	No Table inputs
TREC	Surface temperature at which surface recession commences (°R)	2235.	INDATA	Real	Left the same but since surface recession = 0, not pertinent in our applications
TS	Temperature values for surface recession table, SR (°R)	See MAINDA	MAINDA	Real (50)	
TSUBL	Temperature at which sublimation of carbon begins (°R)	2235.	INDATA	Real	Assumed to be the same value as for Apollo material

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
TTABLE	Time where either the time increment or the print interval changes (s). Calculated internally if DELTT(1) $\leq$ 0.	—	INPUT	Real (20)	Used if DELTT is not calculated internally
TV	Sink temperature (°R)	535.	INDATA	Real	—
TXK	TXK(1,m) - Temperature values for thermal conductivity table, XK(1,m) (°R) (Backup materials)	See MAINDA	MAINDA	Real (20,12)	—
TXO	Initial temperature at front surface to be used for TEST2 > 0.	—	—	Real	Not used, TEST2 = 0.
TW	Temperature table corresponding to enthalpy table, HX (°R)	See MAINDA	MAINDA	Real (50)	—
VEL	Velocity table corresponding to heating input table (ft/s)	—	INPUT	Real (300)	Not pertinent to our application, but to avoid division by zero, a small value of VEL must be used, i.e., 10 ft/s
VL	Thickness of virgin material (in.)	—	INPUT	Real	
WX	Wetted length (ft)	1.	INDATA	Real	Set to 1., but not pertinent to our application
WX1, WX2	Wetted length corresponding to minimum angle of attack	—	—	Real Real	Not pertinent to our application
XB	Activation energy in Arrhenius equation	16800.	INDATA/ INPUT	Real	TGA test required to accurately determine

Symbol	Description	Nominal Value	Assigned	Dimension	Comments
XBM	XBM(N) - Thickness of the nth material in the backup structure	See MAINDA	MAINDA	Real	—
XISOTH	Penetration depths: XISOTH (1) and (2) are set up for isotherm penetration depth (°R) XISOTH (3) and (4) are set up for density ratio penetration depths	—	INPUT	Real	—
XK	XK(1,m) - Thermal conductivity (BTU/ft-h-°R) where m is the number of the backup material	See MAINDA	MAINDA	Real	—
XKCHR	Char conductivity (Btu/ft-h-°R)	Table 99998	MAINDA	Real	Assumed to be the same values as for Apollo material
XKREAC	Reaction zone conductivity (Btu/ft-h-°R)	0.		Real	0. = Linear interpolation between char and virgin values
XKVRG	Virgin conductivity (Btu/ft-h-°R)	Table 99996	MAINDA	Real	Values in Table are for FIREX 2373
XNPM	XNPM(n) - Number of nodes in the nth backup material (10 maximum)	See MAINDA	MAINDA	Real	—
XRECES	Table of thicknesses between thermocouples that burnout	—	—	Real (10)	Never used
XTCL	Thermocouple locations (in.), see NXTCL	—	INPUT	Real (15)	Program will not accept thermocouples in backup materials
Z	Conversion factor, 2 RJ/g, used in pressure distribution calculation, see IPRESS	3.15	INDATA	Real	Never used

APPENDIX C

COMPUTER PROCEDURE ITEMS

```
EDIT --- RAS1810.MCOMP.CNTL ------------------------------- COLUMNS 001 072
COMMAND ===>                                                SCROLL ===> HALF
****** ***************************** TOP OF DATA ****************************
000010 //RAS1810F JOB *,RAS1810,REGION=2048K,TIME=1,PRTY=1,
000020 //   MSGCLASS=H,MSGLEVEL=(2,1),NOTIFY=RAS1810
000030 /*JOBPARM  LINES=999,COPIES=001
000040 //*
000050 //*
000060 //MAIN     EXEC XF4LIB,NOPREP=,
000070 //     NONAME=,TYPE=FORTV,CERROR=12,
000080 //  CPARM='OPT(0),FLAG(I),',
000090 //             UIDENT='RAS1810.STABII',
000100 //  PPARM='R=,A=,C=,P=@*0123456789',
000110 //             LPARM='',MEMBER=MAIN
000120 //*
000130 //* = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
****** **************************** BOTTOM OF DATA ****************************
```

```
EDIT --- RAS1810.MDCDMP.CNTL ------------------------------- COLUMNS 001 072
COMMAND ===> _                                              SCROLL ===> HALF
****** ***************************** TOP OF DATA ****************************
000010 //RAS1810F JOB *,RAS1810,REGION=2048K,TIME=1,PRTY=1,
000020 //   MSGCLASS=H,MSGLEVEL=(2,1),NOTIFY=RAS1810
000030 /*JOBPARM  LINES=999,COPIES=001
000040 //*
000050 //*
000060 //MAINDA   EXEC XF4LIB,NOPREP=,
000070 //     NONAME=,TYPE=FORTV,CERROR=12,
000080 //  CPARM='OPT(0),FLAG(I),',
000090 //             UIDENT='RAS1810.STABII',
000100 //  PPARM='R=,A=,C=,P=@*0123456789',
000110 //             LPARM='',MEMBER=MAINDA
000120 //*
000130 //* = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
****** **************************** BOTTOM OF DATA ****************************
```

```
----- LINK EXECUTABLE LOAD MODULE - DEFINITION -------------------------------
COMMAND INPUT ===>
COMMANDS ARE:  BLANK (TO SET UP LINK) OR GO (TO SKIP REMAINING PANELS)

PROGRAM NAME  ===> STABII

PRIMARY LINK LIBRARY:
      PROJECT ===> RAS1810
      LIBRARY ===> STABII
      TYPE    ===> LOAD

PRIMARY SOURCE LIBRARY:
      TYPE    ===> FORT

PRINT OUTPUT:
      CLASS   ===> D        - A (PRINTER), O (DELETE), H (HOLD),
                              * (TERMINAL), ¬ (NONE) OR BLANK (LIST DATASET)
      LIST ID ===>          - BLANK FOR LIBRARY VALUE, NOW STABII
```

```
----- LINK EXECUTABLE LOAD MODULE - LIBRARY/OPTIONS --- LIB LIST MEMBER APPLIED

LOAD LIBRARY DSNAME (WITHOUT MEMBER NAME):
    TARGET   ===> 'RAS1810.PGM.LOAD'                          PROGRAM:  STABII

LINKAGE EDITOR OPTIONS - TERM AND LIST ARE ALWAYS PROVIDED
    ===> MAP,SIZE=(400K,100K)

SECONDARY LINK LIBRARIES:          (PRIMARY LIBRARY IS ALWAYS FIRST)
    LINK1    ===> 'SYS1.FORTDCG'
    LINK2    ===>
    LINK3    ===>
    LINK4    ===>
    LINK5    ===>
    FORTRAN  ===> VS    - YES, VS  OR NO
    PL/I     ===> NO    - YES (USUAL), TASK (MULTI-TASKING), CMIX OR NO
    IMSL     ===> NO    - SP (SINGLE), DP (DOUBLE) OR NO
    SCIPACK  ===> NO    - LIN (LINPACK) OR NO
    LOCAL    ===> NO    - YES (PROGLIB PLUS FORTDCG AND/OR PLISUBS)
    PLOTTING ===> NO    - YES (D.I.G. ONLY), D (DISSPLA AND D.I.G.), OR NO

CONTROL STATEMENT AND LIBRARY/OPTIONS MEMBERS LAST STORED:  04/01/83 - 17:49:19
        PRIMARY:  'RAS1810.STABII.LOAD'                BY:  RAS1810
```

```
----- LINK EXECUTABLE LOAD MODULE - CONTROL ----------------------------------

LIBRARY/OPTIONS MEMBER (LAST PANEL/ABOVE):   'RAS1810.STABII.FORT(#STABII)'
CONTROL STATEMENT MEMBER (DISPLAYED BELOW):  'RAS1810.STABII.FORT($STABII)'
STORE   ===> YES  - YES OR NO (IN ABOVE MEMBERS)

LINKAGE EDITOR CONTROL STATEMENTS:              (SETSSI ALWAYS PROVIDED)
    ===> INCLUDE SYSLIB(MAIN),SYSLIB(MAINDA)
    ===> ENTRY   MAIN           (STATEMENT GENERATED 02/11/83)
    ===> NAME    STABII(R)
    ===>
    ===>
    ===>
    ===>
    ===>

RECOMMENDED CONTROL STATEMENTS:          (GENERATED IF NO INPUT MEMBER)
    ===> INCLUDE SYSLIB(STABII)
    ===> ENTRY   STABII
    ===> NAME    STABII(R)
```

```
//RAS1810A JOB *,RAS1810,TIME=(0,20),REGION=512K,PRTY=1,
//         NOTIFY=RAS1810,MSGCLASS=A
//*
//RUN  EXEC XCALL,PROG=STABII,
//         LDAD='RAS1810.PGM.LDAD'
//*
//G.FT05F001 DD DISP=SHR,DSN=RAS1810.INPUT.DATA
//*
//G.FT20F001 DD SYSOUT=*
/*
```

```
//RAS1810A JOB *,RAS1810,TIME=(0,20),REGION=512K,PRTY=1,
//         NOTIFY=RAS1810,MSGCLASS=A
//*
//RUN  EXEC XCALL,PROG=STABII,
//         LOAD='RAS1810.PGM.LOAD'
//*
//G.FT05F001 DD DISP=SHR,DSN=RAS1810.INPUT.DATA
//*
//G.FT20F001 DD DISP=OLD,DSN=RAS1810.OUTPUT.DATA
/*
```

AT 16:01:47 ON 04/04/83 - RAS1810.PLOT4.DATA

0.	0.750E+02	0.750E+02
20.	0.780E+02	0.761E+02
40.	0.830E+02	0.802E+02
60.	0.880E+02	0.865E+02
80.	0.970E+02	0.941E+02
100.	0.105E+03	0.102E+03
120.	0.111E+03	0.109E+03
140.	0.117E+03	0.117E+03
160.	0.123E+03	0.123E+03
180.	0.128E+03	0.129E+03
200.	0.134E+03	0.135E+03
220.	0.138E+03	0.139E+03
240.	0.142E+03	0.143E+03
260.	0.144E+03	0.145E+03
280.	0.145E+03	0.146E+03
300.	0.145E+03	0.146E+03
320.	0.146E+03	0.146E+03
340.	0.145E+03	0.145E+03
360.	0.145E+03	0.144E+03
380.	0.144E+03	0.143E+03
400.	0.143E+03	0.142E+03
420.	0.142E+03	0.141E+03
440.	0.141E+03	0.140E+03
460.	0.140E+03	0.139E+03
480.	0.139E+03	0.138E+03
500.	0.138E+03	0.137E+03
520.	0.137E+03	0.136E+03
540.	0.136E+03	0.134E+03
560.	0.136E+03	0.133E+03
580.	0.135E+03	0.132E+03
600.	0.134E+03	0.131E+03

APPENDIX D

SAMPLE INPUT

INPUT. DATA

```
1111.
MAY 1, 1983///2 INCH SLUG OF FIREX 2373///THREE AIR BACKUPS(@ 1.00")///
SAMPLE RUN OF THE ADOPTED MODEL FOR INCLUSION IN APPENDIX E OF THESIS
K(V) = .150 AT LOW TEMPS/ K(V) = .025 AT HIGH TEMPS
&INPUT
ABLC = 0.47, ABLK = .108, CHARC = 0.40, CHARK = 0.065
EMV = .99, HV = 2000., PLPTX = 1., EMC = 0.90
MMM = 2, NMB = 3, NP = 30, NREC = 3, NTRAPT = 5, NXTCL = 5
RHOV = 84.2, TABL = 660., TCHAR = 860., TLIM = 600., VL = 2.00
XTCL = .0625,.125,.25,.50,1.00, XB = 20000., CA = 9500000000.
OELTT = 1., IPRC = 20, NPTT = 1, TTABLE = 0.
ALT = 0.,0.,0.,0.,0.
QCONC = 0.,0.,0.,0.,0.
QRAD = 10.,10.,0.,0.,0.
VEL = 10.,10.,10.,10.,10.
TIME = 0.,200.,201.,400.,600.
&END
9999.
```

APPENDIX E

SAMPLE OUTPUT

INTERPOLATED VARIABLES UNDER CONTROL OF TBLPAK

THERMAL CONDUCTIVITY(R)	XKREAC	= F(CHAR AND VIRGIN VARIABLE PROPERTIES)		
SPECIFIC HEAT(R)	CPREAC	= F(CHAR AND VIRGIN VARIABLE PROPERTIES)		
THERMAL CONDUCTIVITY(C)	XKCHR	SEE TABLE NO	99998	
SPECIFIC HEAT(C)	CPCHR	SEE TABLE NO	99997	
THERMAL CONDUCTIVITY(V)	XKVRG	SEE TABLE NO	99996	
SPECIFIC HEAT(V)	CPVRG	SEE TABLE NO	99995	
SPEC HEAT PROLYSIS GAS	CPGAS	CONSTANT VALUE	0.50	BTU/LBH-R
HEAT OF PYROLYSIS	HV	CONSTANT VALUE	2000.00	BTU/LB
HEAT OF SUBLIMATION	HSUB	CONSTANT VALUE	12000.00	BTU/LBM

TABLE NO 99998 THERMAL CONDUCTIVITY(C) VS TEMPERATURE

TEMPERATURE DEG-R	THERMAL CONDUCTIVITY(C) BTU/FT-HR-R
460.0000	0.0460
760.0000	0.0700
1460.0000	0.0700
1860.0000	0.1460
2060.0000	0.2800
2660.0000	0.4970
2860.0000	0.5250
3710.0000	0.7600
3960.0000	0.7950
4260.0000	0.7950
4860.0000	0.6550
5010.0000	0.5700
5060.0000	0.3030
6000.0000	0.0600

TABLE NO 99997 SPECIFIC HEAT(C) VS TEMPERATURE

TEMPERATURE DEG-R	SPECIFIC HEAT(C) BTU/LB-R
1460.0000	0.3700
2460.0000	0.4120
4960.0000	0.4120
5460.0000	0.4600

TABLE NO 99996 THERMAL CONDUCTIVITY(V) VS TEMPERATURE

TEMPERATURE DEG-R	THERMAL CONDUCTIVITY(V) BTU/FT-HR-R
460.0000	0.1500
560.0000	0.1500
660.0000	0.1080
760.0000	0.0670
860.0000	0.0250
960.0000	0.0250
1460.0000	0.0250

TABLE NO 99995 SPECIFIC HEAT(V) VS TEMPERATURE

TEMPERATURE DEG-R	SPECIFIC HEAT(V) BTU/LB-R
0.0000E+00	0.4700
560.0000	0.4700
660.0000	0.4700
760.0000	0.4700
860.0000	0.4700
960.0000	0.4700
1060.0000	0.4700

STAB II CHARRING ABLATION PROGRAM

MAY 1, 1983///2 INCH SLUG OF FIREX 2373///THREE AIR BACKUPS(@ 1.00")///
SAMPLE RUN OF THE ADOPTED MODEL FOR INCLUSION IN APPENDIX E OF THESIS
K(V) = .150 AT LOW TEMPS/ K(V) = .025 AT HIGH TEMPS

INPUT AND INITIALIZATION DATA

LOCATION SUMMARY
CONSTANT FACTORS WILL BE USED. ANGLE-OF-ATTACK HISTORY IS IGNORED.
FCONV=1.00000E+00 FRAD=1.00000E+00 WX=1.00000E+00 (FT) PLPTX=1.00000E+00

INITIAL TIME=0.0000E+00 (SEC) TIME LIMIT=6.0000E+02 (SEC)

TIME (SEC)	TIME STEP (SEC)	PRINT CONTROL (TIME STEP/PRINT)
0.0000E+00	1.0000E+00	20

ARRHENIUS EQUATION PARAMETERS
N= 0.1000000E+01 A= 0.9500000E+10 B= 0.2000000E+05

TABL=6.60000E+02 (DEG-R)	ABLC=4.70000E-01 (BTU/LB-R)	RHOV=8.42000E+01 (LB/FT3)	NP=30		
TCHAR=8.60000E+02 (DEG-R)	ABLK=1.08000E-01 (BTU/HR-FT-R)	RHOC=2.00000E+01 (LB/FT3)	MMM= 2		
TREC=2.23500E+03 (DEG-R)	CHARC=4.00000E-01 (BTU/LB-R)	RHOS=1.60000E+01 (LB/FT3)	NTURBT= 1		
TV=5.35000E+02 (DEG-R)	CHARK=6.50000E-02 (BTU/HR-FT-R)	FV=1.00000E+00	ITHIN= 1		
VL=2.00000E+00 (IN)	HV=2.00000E+03 (BTU/LB-R)	OHC=5.00000E+03 (BTU/LB)	EMV=9.90000E-01		
FBLOWL=1.00000E+00	CPGAS=5.00000E-01 (BTU/LB-R)	HSUB=1.20000E+04 (BTU/LB)	EMC=9.00000E-01		
FBLOWT=1.00000E+00	RTR=8.00000E+04	H300=1.29060E+02 (BTU/LB)	SHAPEF=5.53200E-02		

SURFACE RECESSION TABLE

TEMPERATURE (DEG-R)	SURFACE RECESSION (IN/SEC)
0.00000E+00	0.00000E+00
2.00000E+03	0.00000E+00
4.00000E+03	0.00000E+00

THERMOCOUPLE LOCATIONS (IN)
6.25000000E-02 1.25000000E-01 2.50000000E-01 5.00000000E-01 1.00000000E+00

REFERENCE TRAJECTORY ***NOTE IF QCONC(1).LT.0.0, THEN THE Q RADIATIVE ARRAY CONTAINS SURFACE TEMPERATURE (DEG-F) AND THE Q CONVECTIVE ARRAY IS NOT USED.

NO. OF TRAJECTORY POINTS = 5

TIME (SEC)	Q CONVECTIVE (BTU/FT2-SEC)	Q RADIATIVE (BTU/FT2-SEC)	VELOCITY (FT/SEC)	ALTITUDE (FT)	ANGLE OF ATTACK (DEG)
0.00000E+00	0.00000E+00	1.00000E+01	1.00000E+01	0.00000E+00	0.00000E+00
2.00000E+02	0.00000E+00	1.00000E+01	1.00000E+01	0.00000E+00	0.00000E+00
2.01000E+02	0.00000E+00	0.00000E+00	1.00000E+01	0.00000E+00	0.00000E+00
4.00000E+02	0.00000E+00	0.00000E+00	1.00000E+01	0.00000E+00	0.00000E+00
6.00000E+02	0.00000E+00	0.00000E+00	1.00000E+01	0.00000E+00	0.00000E+00

PROPERTIES OF THE BACKUP STRUCTURE

NO. OF MATERIALS IN BACK-UP SHIELD= 3
TOTAL NUMBER OF NODES IN BACK-UP SHIELD= 9
THICKNESS OF BACK-UP SHIELD= 3.00000E+00

TEMPERATURE (DEG-R) THERMAL CONDUCTIVITY (BTU/HR-FT-R) SPECIFIC HEAT (BTU/LB-R)

TEMPERATURE	THERMAL CONDUCTIVITY	TEMPERATURE	SPECIFIC HEAT
0.00000E+00	1.30000E-02	0.00000E+00	2.39000E-01
5.60000E+02	1.60000E-02	9.60000E+02	2.48000E-01
6.60000E+02	1.80000E-02	1.96000E+03	2.77000E-01
9.60000E+02	2.50000E-02		
1.26000E+03	3.00000E-02		
1.96000E+03	4.10000E-02		

TEMPERATURE	THERMAL CONDUCTIVITY	TEMPERATURE	SPECIFIC HEAT
0.00000E+00	1.30000E-02	0.00000E+00	2.39000E-01
5.60000E+02	1.60000E-02	9.60000E+02	2.48000E-01
6.60000E+02	1.80000E-02	1.96000E+03	2.77000E-01
9.60000E+02	2.50000E-02		
1.26000E+03	3.00000E-02		
1.96000E+03	4.10000E-02		

TEMPERATURE	THERMAL CONDUCTIVITY	TEMPERATURE	SPECIFIC HEAT
0.00000E+00	1.30000E-02	0.00000E+00	2.39000E-01
5.60000E+02	1.60000E-02	9.60000E+02	2.48000E-01
6.60000E+02	1.80000E-02	1.96000E+03	2.77000E-01
9.60000E+02	2.50000E-02		
1.26000E+03	3.00000E-02		
1.96000E+03	4.10000E-02		

MATERIAL	DENSITY (LB/FT3)	THICKNESS (IN)	EMISSIVITY FRONT	EMISSIVITY BACK	NODES/MATERIAL
1	7.1000E-02	1.0000E+00	6.5000E-01	6.5000E-01	3.0000E+00
2	7.1000E-02	1.0000E+00	6.5000E-01	6.5000E-01	3.0000E+00
3	7.1000E-02	1.0000E+00	6.5000E-01	6.5000E-01	3.0000E+00

ADDITIONAL DATA FOR INDIVIDUAL MATERIALS IN BACKUP STRUCTURE

MATERIAL	FILM COEFFICIENT (BTU/HR-FT2-R)	GAP THICKNESS (IN)	FTEST	BTEST
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

CABIN TEMPERATURE= 5.35000E+02 (DEG-R) HEAT LOSS TO CABIN= 0.00000E+00 (BTU/HR-FT2-SEC)

VIEW FACTOR TO CABIN= 0.00000E+00 FILM COEFFICIENT TO CABIN= 0.00000E+00 (BTU/HR-FT2-R)

TEMPERATURE DISTRIBUTION IN TEST SPECIMEN IS UNIFORM AND EQUAL TO 5.3500E+02 (DEG-R)

TRAJECTORY WITH LOCAL HEATING RATES (TURBULENT CASE)

NO. OF TRAJECTORY POINTS = 5

TIME (SEC)	VELOCITY (FT/SEC)	ALTITUDE (FT)	LOCAL Q CONVECTIVE (BTU/FT2-SEC)	LOCAL Q RADIATIVE (BTU/FT2-SEC)	LOCAL REYNOLDS NO.	TURBULENT FACTOR
0.0000000E+00	1.0000000E+01	0.0000000E+00	0.0000000E+00	1.0000000E+01	0.0000000E+00	1.0000000E+00
2.0000000E+02	1.0000000E+01	0.0000000E+00	0.0000000E+00	1.0000000E+01	0.0000000E+00	1.0000000E+00
2.0100000E+02	1.0000000E+01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E+00
4.0000000E+02	1.0000000E+01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E+00
6.0000000E+02	1.0000000E+01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E+00

TIME	INTEGRATED Q CONVECTIVE	INTEGRATED Q RADIATIVE	INTEGRATED Q CON. + Q RAD.
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
2.0000000E+02	0.0000000E+00	2.0000000E+03	2.0000000E+03
2.0100000E+02	0.0000000E+00	2.0050000E+03	2.0050000E+03
4.0000000E+02	0.0000000E+00	2.0050000E+03	2.0050000E+03
6.0000000E+02	0.0000000E+00	2.0050000E+03	2.0050000E+03

OUTPUT DATA.

****** TIME= 0.00000E+00 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 1.00000E+01	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN= 1.00000E+01	QRERAD= 0.00000E+00	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 5.00000E+00	TQRERAD= 0.00000E+00	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-1.97475E+00	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 5.00000E+00	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 8.02000E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 1.00000E+00

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	157.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	77.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.81704437E+02
0.12500000E+00	0.75347855E+02
0.25000000E+00	0.75000290E+02
0.50000000E+00	0.74999710E+02
0.10000000E+01	0.74999695E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH DF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH DF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.00000E+00

EQUIVALENT TEST SPECIMEN LOSS= 0.00000 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 2.00000 (IN)

****** TIME= 2.00000E+01 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 1.00000E+01 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 4.87247E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 4.87247E+00
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN= 9.47550E+00 QRERAD= 5.24504E-01 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSID2= 0.00000E+00 TQDXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.96951E+02 TQRERAD= 8.04873E+00 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-1.31849E+02 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.05000E+02 HTX= 1.29062E+02 PLPT= 1.00000E+00
QDXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 7.37210E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 2.10000E+01

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MI COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	606.0	77.25	0.8843	0.4872469E+01	0.0000000E+00	0.0000000E+00	14.6959
0.06897	148.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	92.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	78.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	75.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTIDN IN THE BACK-UP STRUCTURE (OEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTEO THERMDCDUPLE LOCATIONS OEPTH - (IN), TEMPERATURE - (DEG-F)

OEPTH	TEMPERATURE
0.62500000E-01	0.17465094E+03
0.12500000E+00	0.99802948E+02
0.25000000E+00	0.76346069E+02
0.50000000E+00	0.74997757E+02
0.10000000E+01	0.74997742E+02

PENETRATIDN OEPTHS (IN)

MAX DEPTH DF 200.00 (DEG-F) ISOTHERM= 0.61245E-01
MAX OEPTH OF 400.00 (DEG-F) ISOTHERM= 0.31076E-01

DEPTH DF 200.00 (OEG-F) ISDTHERM= 0.61245E-01 OEPTH DFO.10000 OENSITY RATIO= 0.00000E+00
OEPTH DF 400.00 (OEG-F) ISOTHERM= 0.31076E-01 DEPTH DFO.90000 DENSITY RATIO= 0.93334E-02

EQUIVALENT TEST SPECIMEN LOSS= 0.00356 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.99644 (IN)

****** TIME= 4.00000E+01 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RAOIATIVE= 1.00000E+01 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATIDN RATE= 4.23348E+00 CHAR ABLATIDN RATE= 0.00000E+00 TOTAL ABLATION RATE= 4.23348E+00
RECESSION OEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN= 9.44325E+00 QRERAO= 5.56749E-01 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
OHDT WALL= 0.00000E+00 QSID2= 0.00000E+00 TQOXIO= 0.00000E+00 BCDF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 3.86139E+02 TQRERAD= 1.88609E+01 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-1.35525E+02 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRAOX= 4.05000E+02 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXIO= 0.00000E+00 TQBLOCK= 0.00000E+00 RHDST= 6.47926E+01 WX= 1.00000E+00

TEST SPECIMEN PRDFILES AT THE END DF THE TIME STEP, TIME= 4.10000E+01

X (IN)	TEMPERATURE (OEG-F)	DENSITY (LB/FT3)	THETA	M DDT (LB/FT2-HR)	M CDKE (LB/FT2-HR)	MT CDKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	621.0	68.38	0.7473	0.4233484E+01	0.0000000E+00	0.0000000E+00	14.6959
0.06897	204.1	84.20	1.0000	0.8236020E-04	0.0000000E+00	0.0000000E+00	14.6959

0.13793	118.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	88.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	78.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14 6959
0.68965	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84 20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84 20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)
0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.22916003E+03
0.12500000E+00	0.13027545E+03
0.25000000E+00	0.81557495E+02
0.50000000E+00	0.75017883E+02
0.10000000E+01	0.74997742E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.72305E-01
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.36563E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.72305E-01 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.36563E-01 DEPTH OF0.90000 DENSITY RATIO= 0.41670E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.01589 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.98411 (IN)

****** TIME= 6.00000E+01 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
0 CONVECTIVE= 0.00000E+00 0 RADIATIVE= 1.00000E+01 ANGLE OF ATTACK= 0.00000E+00

GAS ABLATION RATE= 3.35246E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 3.35246E+00
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

DIN= 9.41201E+00	QRERAD= 5.87989E-01	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 5.74688E+02	TQRERAD= 3.03123E+01	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-1.38947E+02	PL= 1.4696OE+01
QSUBL= 0.00000E+00	TQRADX= 6.05000E+02	HTX= 1.29062E+02	PLPT= 1.00000E+00
QDXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 5.74914E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 6.10000E+01

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	634.9	61.18	0.6366	0.3352455E+01	0.0000000E+00	0.0000000E+00	14.6959
0.06897	251.0	84.20	1.0000	0.5850743E-03	0.0000000E+00	0.0000000E+00	14.6959
0.13793	143.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	101.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	84.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	78.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)
0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.27523242E+03
0.12500000E+00	0.15850691E+03
0.25000000E+00	0.89749390E+02
0.50000000E+00	0.75146271E+02
0.10000000E+01	0.74997742E+02

PENETRATION OEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.10164E+00
MAX OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.42195E-01

DEPTH OF 200.00 (OEG-F) ISOTHERM= 0.10164E+00 OEPTH OFO.10000 OENSITY RATIO= 0.00000E+00
OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.42195E-01 DEPTH OFO.90000 OENSITY RATIO= 0.49989E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.01906 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.98094 (IN)

****** TIME= 8.00000E+01 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
O CONVECTIVE= 0.00000E+00 O RAOIATIVE= 1.00000E+01 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 2.53944E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 2.53944E+00
RECESSION OEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

OIN= 9.38506E+00 ORERAD= 6.14942E-01 TOSUBL= 0.00000E+00 ALPHA= 1.07123E+00
OHOT WALL= 0.00000E+00 OSIO2= 0.00000E+00 TOOXID= 0.00000E+00 BCOF= 0.00000E+00
OWB= 0.00000E+00 TOIN= 7.62649E+02 TORERAD= 4.23512E+01 G= 0.00000E+00
OBLOCK= 0.00000E+00 TOHW= 0.00000E+00 HTX-HW=-1.41797E+02 PL= 1.46960E+01
OSUBL= 0.00000E+00 TORAOX= 8.05000E+02 HTX= 1.29062E+02 PLPT= 1.00000E+00
OOXIO= 0.00000E+00 TOBLOCK= 0.00000E+00 RHOST= 5.21689E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE ENO OF THE TIME STEP, TIME= 8.10000E+01

X (IN)	TEMPERATURE (OEG-F)	OENSITY (LB/FT3)	THETA	M OOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	646.4	55.95	0.5567	0.2539436E+01	0.0000000E+00	0.0000000E+00	14 6959
0.06897	289.9	84.20	0.9999	0.2704849E-02	0.0000000E+00	0.0000000E+00	14.6959
0.13793	165.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	115.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14 6959
0.27586	92.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	81.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	77.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	75.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.31342798E+03
0.12500000E+00	0.18283084E+03
0.25000000E+00	0.99289917E+02
0.50000000E+00	0.75514542E+02
0.10000000E+01	0.74997742E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.11866E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.47658E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.11866E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.47658E-01 DEPTH OF0.90000 DENSITY RATIO= 0.53414E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02036 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97964 (IN)

****** TIME= 1.00000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 1.00000E+01	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 2.06528E+00	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 2.06528E+00
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN= 9.36450E+00	QRERAD= 6.35502E-01	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 9.50134E+02	TQRERAD= 5.48658E+01	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-1.43912E+02	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 1.00500E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 4.85490E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 1.01000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	654.8	52.40	0.5024	0.2065276E+01	0.0000000E+00	0.0000000E+00	14.6959
0.06897	320.9	84.19	0.9998	0.7749949E-02	0.0000000E+00	0.0000000E+00	14.6959
0.13793	183.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	128.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	100.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	85.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	79.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	76.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

0.75862	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE OISTRIBUTION IN THE BACK-UP STRUCTURE (OEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTEO THERMOCOUPLE LOCATIONS OEPTH - (IN), TEMPERATURE - (OEG-F)

OEPTH	TEMPERATURE
0.62500000E-01	0.34391846E+03
0.12500000E+00	0.20273407E+03
0.25000000E+00	0.10902299E+03
0.50000000E+00	0.76223984E+02
0.10000000E+01	0.74997742E+02

PENETRATION OEPTHS (IN)

MAX OEPTH OF 200.00 (OEG-F) ISOTHERM= 0.12953E+00
MAX OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.52638E-01

OEPTH OF 200.00 (OEG-F) ISOTHERM= 0.12953E+00 OEPTH OFO.10000 OENSITY RATIO= 0.00000E+00
OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.52638E-01 OEPTH OFO.90000 OENSITY RATIO= 0.55127E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02102 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97898 (IN)

****** TIME= 1.20000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAO= 1.00000E+00 VELOCITY= 1.00000E+01
O CONVECTIVE= 0.00000E+00 O RAOIATIVE= 1.00000E+01 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 1.94034E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 1.94034E+00
RECESSION OEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

OIN= 9.34843E+00 ORERAO= 6.51563E-01 TOSUBL= 0.00000E+00 ALPHA= 1.07123E+00
OHOT WALL= 0.00000E+00 OSIO2= 0.00000E+00 TOOXIO= 0.00000E+00 BCOF= 0.00000E+00
OWB= 0.00000E+00 TOIN= 1.13727E+03 TORERAO= 6.77347E+01 G= 0.00000E+00
OBLOCK= 0.00000E+00 TOHW= 0.00000E+00 HTx-HW=-1.45531E+02 PL= 1.46960E+01
OSUBL= 0.00000E+00 TORAOX= 1.20500E+03 HTx= 1.29062E+02 PLPT= 1.00000E+00
OOXIO= 0.00000E+00 TOBLOCK= 0.00000E+00 RHOST= 4.59570E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 1.21000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	660.7	49.84	0.4631	0.1940341E+01	0.0000000E+00	0.0000000E+00	14.6959
0.06897	344.9	84.17	0.9995	0.1650592E-01	0.0000000E+00	0.0000000E+00	14.6959
0.13793	197.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	139.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	108.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	91.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	82.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	77.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	76.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.36731006E+03
0.12500000E+00	0.21829146E+03
0.25000000E+00	0.11830885E+03
0.50000000E+00	0.77316925E+02
0.10000000E+01	0.74997742E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.13675E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.56924E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.13675E+00 DEPTH OF 0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.56924E-01 DEPTH OF 0.90000 DENSITY RATIO= 0.56176E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02142 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97858 (IN)

****** TIME= 1.40000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00.	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 1.00000E+01	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 9.59588E-01	CHAR ABLATIDN RATE= 0.00000E+00	TOTAL ABLATION RATE= 9.59588E-01
RECESSION DEPTH= 0.00000E+00	RECESSIDN RATE= 0.00000E+00	SUBLIMATIDN RATE= 0.00000E+00

QIN= 9.25157E+00	QRERAD= 7.48427E-01	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXIO= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.32415E+03	TQRERAD= 8.08477E+01	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-1.54734E+02	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRAOX= 1.40500E+03	HTx= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 4.38073E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE ENO OF THE TIME STEP, TIME= 1.41000E+02

X (IN)	TEMPERATURE (OEG-F)	DENSITY (LB/FT3)	THETA	M OOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT CDKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	603.1	47.66	0.4300	0.9595881E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	362.0	84.13	0.9988	0.2779917E-01	0.0000000E+00	0.0000000E+00	14.6959
0.13793	208.5	84.20	1.0000	0.1114678E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	149.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	115.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	96.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	85.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	79.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	76.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	75.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE OISTRIBUTION IN THE BACK-UP STRUCTURE (OEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS OEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.38089697E+03
0.12500000E+00	0.23005846E+03
0.25000000E+00	0.12683690E+03
0.50000000E+00	0.78778198E+02
0.10000000E+01	0.74997742E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.14789E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.61154E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.14789E+00 DEPTH OFO.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.58101E-01 DEPTH OFO.90000 DENSITY RATIO= 0.56981E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02172 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97828 (IN)

****** TIME= 1.60000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 1.00000E+01	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 8.66288E-01	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 8.66288E-01
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN= 9.22081E+00	QRERAD= 7.79191E-01	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.51149E+03	TQRERAD= 9.35149E+01	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-1.57477E+02	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 1.60500E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 4.17116E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 1.61000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	587.3	45.57	0.3993	0.8662884E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	372.2	84.07	0.9979	0.3760283E-01	0.0000000E+00	0.0000000E+00	14.6959
0.13793	217.0	84.20	1.0000	0.1636567E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	158.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	122.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	101.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	88.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	81.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	78.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	76.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.38982471E+03
0.12500000E+00	0.23875844E+03
0.25000000E+00	0.13450587E+03
0.50000000E+00	0.80555649E+02
0.10000000E+01	0.74998291E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.15791E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.63313E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.15791E+00 DEPTH OF 0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.60053E-01 DEPTH OF 0.90000 DENSITY RATIO= 0.57683E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02199 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97801 (IN)

****** TIME= 1.80000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 1.00000E+01	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 8.22016E-01	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 8.22016E-01
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN= 9.20052E+00	QRERAD= 7.99479E-01	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.69878E+03	TQRERAD= 1.06215E+02	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-1.59244E+02	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 1.80500E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.98627E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 1.81000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	579.7	43.71	0.3693	0.8220159E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	379.5	84.00	0.9967	0.4650396E-01	0.0000000E+00	0.0000000E+00	14.6959
0.13793	223.8	84.20	1.0000	0.2217318E-03	0.0000000E+00	0.0000000E+00	14.6959

0.20690	165.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	129.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	106.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	92.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	83.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	79.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	77.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE OISTRIBUTION IN THE BACK-UP STRUCTURE (OEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTEO THERMOCOUPLE LOCATIONS OEPTH - (IN), TEMPERATURE - (OEG-F)

OEPTH	TEMPERATURE
0.62500000E-01	0.39635254E+03
0.12500000E+00	0.24559634E+03
0.25000000E+00	0.14138330E+03
0.50000000E+00	0.82579147E+02
0.10000000E+01	0.75000763E+02

PENETRATION OEPTHS (IN)

MAX OEPTH OF 200.00 (OEG-F) ISOTHERM= 0.16621E+00
MAX OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.64830E-01

OEPTH OF 200.00 (DEG-F) ISOTHERM= 0.16621E+00 OEPTH OF0.10000 OENSITY RATIO= 0.00000E+00
OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.61896E-01 OEPTH OF0.90000 OENSITY RATIO= 0.58333E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02224 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97776 (IN)

****** TIME= 2.00000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAO= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RAOIATIVE= 1.00000E+01 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 7.60770E-01 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 7.60770E-01

RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=	9.17898E+00	QRERAD=	8.21017E-01	TQSUBL=	0.00000E+00	ALPHA=	1.07123E+00
QHOT WALL=	0.00000E+00	QSIO2=	0.00000E+00	TQOXID=	0.00000E+00	BCOF=	0.00000E+00
QWB=	0.00000E+00	TQIN=	1.88602E+03	TQRERAD=	1.18978E+02	G=	0.00000E+00
QBLOCK=	0.00000E+00	TQHW=	0.00000E+00	HTX-HW=	-1.61086E+02	PL=	1.46960E+01
QSUBL=	0.00000E+00	TQRADX=	2.00500E+03	HTX=	1.29062E+02	PLPT=	1.00000E+00
QDXID=	0.00000E+00	TQBLOCK=	0.00000E+00	RHOST=	3.79606E+01	WX=	1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 2.01000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	572.4	41.80	0.3392	0.7607699E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	384.7	83.91	0.9953	0.5418284E-01	0.0000000E+00	0.0000000E+00	14.6959
0.13793	229.5	84.20	1.0000	0.3632151E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	172.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	135.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	111.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	95.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	86.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	80.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	77.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	76.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14 6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.40089722E+03
0.12500000E+00	0.25115137E+03
0.25000000E+00	0.14755309E+03
0.50000000E+00	0.84776962E+02
0.10000000E+01	0.75009003E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.17340E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.17340E+00 DEPTH OF 0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.63338E-01 DEPTH OF 0.90000 DENSITY RATIO= 0.58944E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02247 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97753 (IN)

****** TIME= 2.20000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 7.54362E-02 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 7.54362E-02
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-1.67083E-01 QRERAD= 1.67083E-01 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.88574E+03 TQRERAD= 1.24258E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-7.33060E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRAOX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76622E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 2.21000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	362.3	41.66	0.3375	0.7543623E-01	0.0000000E+00	0.0000000E+00	14.6959
0.06897	356.2	83.83	0.9943	0.2610629E-01	0.0000000E+00	0.0000000E+00	14.6959
0.13793	234.9	84.20	1.0000	0.4598494E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	177.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	140.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	115.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	99.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	89.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	82.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	78.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	76.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

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1.99999        75.0        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959

TEMPERATURE OISTRIBUTION IN THE BACK-UP STRUCTURE  (OEG-F)
0.7500000E+02   0.7500000E+02   0.7500000E+02   0.7500000E+02   0.7500000E+02   0.7500000E+02
0.7500000E+02   0.7500000E+02   0.7500000E+02

TEMPERATURES AT SELECTEO THERMOCOUPLE LOCATIONS   OEPTH - (IN),  TEMPERATURE - (OEG-F)

                          OEPTH                          TEMPERATURE
                    0.62500000E-01                    0.36167700E+03
                    0.12500000E+00                    0.25270477E+03
                    0.25000000E+00                    0.15312778E+03
                    0.50000000E+00                    0.87090210E+02
                    0.10000000E+01                    0.75024841E+02

PENETRATION OEPTHS  (IN)

   MAX OEPTH OF  200.00 (OEG-F) ISOTHERM= 0.18012E+00
   MAX OEPTH OF  400.00 (OEG-F) ISOTHERM= 0.6594OE-01

   OEPTH OF  200.00 (OEG-F) ISOTHERM= 0.18012E+00      OEPTH OFO.10000 OENSITY RATIO= 0.00000E+00
   OEPTH OF  400.00 (OEG-F) ISOTHERM= 0.00000E+00      OEPTH OFO.90000 OENSITY RATIO= 0.59065E-01

EQUIVALENT TEST SPECIMEN LOSS=   0.02252 (IN)      EQUIVALENT TEST SPECIMEN LENGTH=   1.97748 (IN)

****** TIME= 2.40000E+02          TIME STEP= 1.00000E+00

             FCONV= 1.00000E+00              FRAO= 1.00000E+00              VELOCITY= 1.00000E+01
     Q CONVECTIVE= 0.00000E+00       Q RAOIATIVE= 0.00000E+00      ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 2.64821E-02  CHAR ABLATION RATE= 0.00000E+00  TOTAL ABLATION RATE= 2.64821E-02
  RECESSION OEPTH= 0.00000E+00     RECESSION RATE= 0.00000E+00     SUBLIMATION RATE= 0.00000E+00

       OIN=-1.19729E-01      ORERAO= 1.19729E-01       TQSUBL= 0.00000E+00       ALPHA= 1.07123E+00
  OHOT WALL= 0.00000E+00       QSI02= 0.00000E+00       TQOXIO= 0.00000E+00        BCOF= 0.00000E+00
       OWB= 0.00000E+00        TQIN= 1.88296E+03      TQRERAO= 1.27045E+02           G= 0.00000E+00
    QBLOCK= 0.00000E+00        TQHW= 0.00000E+00      HTX-HW=-6.02842E+01          PL= 1.46960E+01
     QSUBL= 0.00000E+00       TQRAOX= 2.01000E+03         HTX= 1.29062E+02        PLPT= 1.00000E+00
     QOXIO= 0.00000E+00      TQBLOCK= 0.00000E+00        RHOST= 3.76453E+01          WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE ENO OF THE TIME STEP, TIME= 2.41000E+02

   X        TEMPERATURE    OENSITY     THETA       M OOT          M COKE         MT COKE       PRESSURE
  (IN)        (OEG-F)     (LB/FT3)                (LB/FT2-HR)    (LB/FT2-HR)    (LB/FT2-HR)     (PSI)
0.00000       311.3        41.64      0.3373  0.2648206E-01  0.0000000E+00  0.0000000E+00     14.6959
0.06897       323.8        83.81      0.9939  0.1134093E-01  0.0000000E+00  0.0000000E+00     14.6959
0.13793       238.1        84.20      1.0000  0.5390195E-03  0.0000000E+00  0.0000000E+00     14.6959
0.20690       182.9        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.27586       145.6        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.34483       120.0        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.41379       102.9        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.48276        91.5        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.55172        84.3        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.62069        80.0        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.68965        77.5        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
0.75862        76.2        84.20      1.0000  0.0000000E+00  0.0000000E+00  0.0000000E+00     14.6959
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0.82759	75.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.32676440E+03
0.12500000E+00	0.25186542E+03
0.25000000E+00	0.15818082E+03
0.50000000E+00	0.89466934E+02
0.10000000E+01	0.75051147E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.1855BE+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.6594OE-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.1855BE+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59107E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02253 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97746 (IN)

****** TIME= 2.60000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 1.16735E-02 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 1.16735E-02
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-9.82032E-02 QRERAD= 9.82032E-02 TOSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSID2= 0.00000E+00 TQDXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.88079E+03 TQRERAD= 1.29205E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-5.33547E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QDXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76400E+01 WX= 1.00000E+00

TEST SPECIMEN PRDFILES AT THE END DF THE TIME STEP, TIME= 2.61000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M CDKE (LB/FT2-HR)	MT CDKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	283.6	41.64	0.3372	0.1167347E-01	0.0000000E+00	0.0000000E+00	14.6959
0.06897	296.6	83.79	0.9937	0.5698841E-02	0.0000000E+00	0.0000000E+00	14.6959
0.13793	237.5	84.20	0.9999	0.5498368E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	186.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	150.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	124.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	106.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	94.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	86.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	81.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	78.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	76.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.1	84 20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTIDN IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMDCDUPLE LDCATIDNS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.29842065E+03
0.12500000E+00	0.24789476E+03
0.25000000E+00	0.16248685E+03
0.50000000E+00	0.91861115E+02
0.10000000E+01	0.75092194E+02

PENETRATIDN DEPTHS (IN)

MAX DEPTH DF 200.00 (DEG-F) ISDTHERM= 0.18888E+00
MAX DEPTH OF 400.00 (DEG-F) ISDTHERM= 0.65940E-01

DEPTH DF 200.00 (DEG-F) ISDTHERM= 0.18888E+00 DEPTH DFO.10000 DENSITY RATID= 0.00000E+00
DEPTH DF 400.00 (DEG-F) ISDTHERM= 0.00000E+00 DEPTH DFO.90000 DENSITY RATID= 0.59124E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02254 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97746 (IN)

****** TIME= 2.80000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 0.00000E+00	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 6.10840E-03	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 6.10840E-03
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN=-8.42038E-02	QRERAD= 8.42039E-02	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.87898E+03	TQRERAD= 1.31021E+02	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-4.83852E+01	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRAOX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.76378E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 2.81000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	263.6	41.64	0.3372	0.6108396E-02	0.0000000E+00	0.0000000E+00	14.6959
0.06897	275.2	83.79	0.9936	0.3318309E-02	0.0000000E+00	0.0000000E+00	14.6959
0.13793	233.8	84.20	0.9999	0.5033505E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	189.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	153.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	127.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	109.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	96.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	88.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	82.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	79.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	77.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	76.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.27639990E+03
0.12500000E+00	0.24178519E+03
0.25000000E+00	0.16582486E+03
0.50000000E+00	0.94247910E+02
0.10000000E+01	0.75149750E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59132E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02254 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97746 (IN)

****** TIME= 3.00000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	D RADIATIVE= 0.00000E+00	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 3.61667E-03	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 3.61667E-03
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

DIN=-7.39953E-02	QRERAD= 7.39954E-02	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00	
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQDXID= 0.00000E+00	BCOF= 0.00000E+00	
DWB= 0.00000E+00	TQIN= 1.87740E+03	TQRERAD= 1.32598E+02	G= 0.00000E+00	
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTx-HW=-4.44792E+01	PL= 1.46960E+01	
QSUBL= 0.00000E+00	TDRADX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00	
QDXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.76368E+01	WX= 1.00000E+00	

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 3.01000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M ODT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	247.8	41.64	0.3372	0.3616674E-02	0.0000000E+00	0.0000000E+00	14.6959
0.06897	258.4	83.79	0.9936	0.2133920E-02	0.0000000E+00	0.0000000E+00	14.6959
0.13793	228.5	84.20	0.9999	0.4331518E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	189.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	156.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	131.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	112.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	99.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	90.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	84.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	80.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	77.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	76.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	75.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.25912109E+03
0.12500000E+00	0.23475372E+03
0.25000000E+00	0.16815147E+03
0.50000000E+00	0.96598602E+02
0.10000000E+01	0.75226212E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18875E+00 DEPTH OF 0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF 0.90000 DENSITY RATIO= 0.59136E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02254 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 3.20000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 2.33507E-03 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 2.33507E-03
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-6.62165E-02 QRERAD= 6.62166E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSID2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.87600E+03 TQRERAD= 1.33996E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-4.13154E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76362E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 3.21000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	235.0	41.64	0.3372	0.2335070E-02	0.0000000E+00	0.0000000E+00	14.6959
0.06897	244.8	83.78	0.9935	0.1464789E-02	0.0000000E+00	0.0000000E+00	14.6959
0.13793	222.6	84.19	0.9999	0.3618414E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	189.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

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 0.27586      158.7        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.34483      133.9        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.41379      115.2        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.48276      101.6        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.55172       92.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.62069       85.4        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.68965       81.1        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.75862       78.4        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.82759       76.9        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.89655       76.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 0.96552       75.5        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.03448       75.2        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.10345       75.1        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.17241       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.24137       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.31034       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.37930       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.44827       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.51723       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.58620       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.65516       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.72413       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.79309       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.86206       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.93102       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959
 1.99999       75.0        84.20     1.0000   0.0000000E+00   0.0000000E+00   0.0000000E+00    14.6959

 TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE  (DEG-F)
0.7500000E+02   0.7500000E+02   0.7500000E+02   0.7500000E+02   0.7500000E+02   0.7500000E+02
0.7500000E+02   0.7500000E+02   0.7500000E+02

 TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS   DEPTH - (IN),  TEMPERATURE - (DEG-F)

                          DEPTH                          TEMPERATURE
                    0.62500000E-01                    0.24523228E+03
                    0.12500000E+00                    0.22759016E+03
                    0.25000000E+00                    0.16955811E+03
                    0.50000000E+00                    0.98883286E+02
                    0.10000000E+01                    0.75323700E+02

 PENETRATION DEPTHS  (IN)

    MAX DEPTH OF  200.00 (DEG-F) ISOTHERM= 0.18996E+00
    MAX DEPTH OF  400.00 (DEG-F) ISOTHERM= 0.65940E-01

    DEPTH OF  200.00 (DEG-F) ISOTHERM= 0.18504E+00      DEPTH OF 0.10000 DENSITY RATIO= 0.00000E+00
    DEPTH OF  400.00 (DEG-F) ISOTHERM= 0.00000E+00      DEPTH OF 0.90000 DENSITY RATIO= 0.59139E-01

 EQUIVALENT TEST SPECIMEN LOSS=   0.02255 (IN)      EQUIVALENT TEST SPECIMEN LENGTH=   1.97745 (IN)

****** TIME= 3.40000E+02          TIME STEP= 1.00000E+00

              FCONV= 1.00000E+00              FRAD= 1.00000E+00              VELOCITY= 1.00000E+01
      Q CONVECTIVE= 0.00000E+00       Q RADIATIVE= 0.00000E+00       ANGLE OF ATTACK= 0.00000E+00
 GAS ABLATION RATE= 1.60452E-03  CHAR ABLATION RATE= 0.00000E+00  TOTAL ABLATION RATE= 1.60452E-03
   RECESSION DEPTH= 0.00000E+00     RECESSION RATE= 0.00000E+00     SUBLIMATION RATE= 0.00000E+00
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QIN= -6.01043E-02	QRERAO= 6.01043E-02	TQSU8L= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSI02= 0.00000E+00	TQOXIO= 0.00000E+00	8COF= 0.00000E+00
QW8= 0.00000E+00	TQIN= 1.87474E+03	TQRERAO= 1.35257E+02	G= 0.00000E+00
Q8LOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW= -3.86996E+01	PL= 1.46960E+01
QSU8L= 0.00000E+00	TQRAOX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXIO= 0.00000E+00	TQ8LOCK= 0.00000E+00	RHOST= 3.76358E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 3.41000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	224.5	41.64	0.3371	0.1604517E-02	0.0000000E+00	0.0000000E+00	14.6959
0.06897	233.5	83.78	0.9935	0.1053031E-02	0.0000000E+00	0.0000000E+00	14.6959
0.13793	216.7	84.19	0.9999	0.2988817E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	188.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	160.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	136.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	117.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	103.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	93.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	86.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	82.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	79.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	77.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	76.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.23379500E+03
0.12500000E+00	0.22069846E+03
0.25000000E+00	0.17019919E+03
0.50000000E+00	0.10106906E+03
0.10000000E+01	0.75444122E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.17857E+00 DEPTH OF 0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF 0.90000 DENSITY RATIO= 0.59140E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 3.60000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 1.06528E-03 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 1.06528E-03
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-5.51703E-02 QRERAD= 5.51703E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.87359E+03 TQRERAD= 1.36408E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-3.64952E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76356E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 3.61000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	215.5	41.64	0.3371	0.1065277E-02	0.0000000E+00	0.0000000E+00	14.6959
0.06897	224.1	83.78	0.9935	0.6942879E-03	0.0000000E+00	0.0000000E+00	14.6959
0.13793	210.9	84.19	0.9999	0.1566626E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	186.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	160.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	138.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	119.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	106.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	95.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	88.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	83.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	79.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	77.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	76.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)
0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.22417368E+03
0.12500000E+00	0.21425117E+03
0.25000000E+00	0.17023410E+03
0.50000000E+00	0.10313628E+03
0.10000000E+01	0.75588577E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.16908E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59141E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 3.80000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 7.84642E-04 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 7.84642E-04
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-5.10965E-02 QRERAD= 5.10965E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSID2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.87253E+03 TQRERAD= 1.37469E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-3.46063E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76354E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 3.81000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	207.9	41.64	0.3371	0.7846416E-03	0.0000000E+00	0.0000000E+00	14.6959
0.06897	215.9	83.78	0.9935	0.5229299E-03	0.0000000E+00	0.0000000E+00	14.6959
0.13793	205.6	84.19	0.9999	0.1263295E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	184.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	161.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	139.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	121.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	108.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	97.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	89.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	84.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	80.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	78.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

0.89655	76.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	76.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.21593707E+03
0.12500000E+00	0.20829994E+03
0.25000000E+00	0.16980856E+03
0.50000000E+00	0.10506940E+03
0.10000000E+01	0.75758286E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.15630E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59142E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 4.00000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 5.95839E-04 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 5.95839E-04
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-4.76683E-02 QRERAD= 4.76683E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.87154E+03 TQRERAD= 1.38456E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-3.29645E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76353E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 4.01000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	201.2	41.64	0.3371	0.5958388E-03	0.0000000E+00	0.0000000E+00	14.6959
0.06897	208.8	83.78	0.9935	0.4039572E-03	0.0000000E+00	0.0000000E+00	14.6959
0.13793	200.5	84.19	0.9999	0.1028682E-03	0.0000000E+00	0.0000000E+00	14.6959
0.20690	182.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	161.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	140.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	123.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	109.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	99.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	91.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	85.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	81.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	79.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	77.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	76.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.20878453E+03
0.12500000E+00	0.20283772E+03
0.25000000E+00	0.16904076E+03
0.50000000E+00	0.10685820E+03
0.10000000E+01	0.75953293E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.6594OE-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.13999E+00 DEPTH OFO.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OFO.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 4.20000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 0.00000E+00	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 1.25768E-04	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 1.25768E-04
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN=-4.47410E-02	QRERAD= 4.47410E-02	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSID2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.87062E+03	TQRERAD= 1.39379E+02	G= 0.00000E+00
QBLOCK= 0.00000E+00	TOHW= 0.00000E+00	HTX-HW=-3.15219E+01	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.76353E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 4.21000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	195.4	41.64	0.3371	0.1257682E-03	0.0000000E+00	0.0000000E+00	14.6959
0.06897	202.6	83.78	0.9935	0.1257682E-03	0.0000000E+00	0.0000000E+00	14.6959
0.13793	195.9	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	180.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	160.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	141.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	125.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	111.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	100.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	92.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	86.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	82.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	79.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	77.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	76.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	75.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE

0.62500000E-01	0.20249783E+03
0.12500000E+00	0.19783723E+03
0.25000000E+00	0.16802580E+03
0.50000000E+00	0.10849809E+03
0.10000000E+01	0.76172256E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.95604E-01 DEPTH OF 0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF 0.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 4.40000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 0.00000E+00	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN=-4.22036E-02	QRERAD= 4.22036E-02	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.86975E+03	TQRERAD= 1.40248E+02	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-3.02393E+01	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.76353E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 4.41000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	190.2	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	197.0	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	191.6	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	177.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	160.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	142.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	126.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	112.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	102.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	93.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	87.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	83.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	80.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	78.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	76.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	76.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.19691660E+03
0.12500000E+00	0.19324577E+03
0.25000000E+00	0.16683929E+03
0.50000000E+00	0.10999397E+03
0.10000000E+01	0.76415985E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 4.60000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-3.99824E-02 QRERAD= 3.99824E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQQXIQ= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.86893E+03 TQRERAD= 1.41069E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-2.90905E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QQXIQ= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76353E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 4.61000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	185.5	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	192.1	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	187.6	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	175.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	159.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

0.34483	142.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	127.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	114.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	103.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	95.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	88.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	84.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	80.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	78.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	77.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	76.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE OISTRIBUTION IN THE BACK-UP STRUCTURE (OEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTEO THERMOCOUPLE LOCATIONS OEPTH - (IN), TEMPERATURE - (OEG-F)

OEPTH	TEMPERATURE
0.62500000E-01	0.19191743E+03
0.12500000E+00	0.18902548E+03
0.25000000E+00	0.16553395E+03
0.50000000E+00	0.11134692E+03
0.10000000E+01	0.76682816E+02

PENETRATION OEPTHS (IN)

MAX OEPTH OF 200.00 (OEG-F) ISOTHERM= 0.18996E+00
MAX OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.65940E-01

OEPTH OF 200.00 (OEG-F) ISOTHERM= 0.00000E+00 OEPTH OFO.10000 OENSITY RATIO= 0.00000E+00
OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.00000E+00 OEPTH OFO.90000 OENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 4.80000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAO= 1.00000E+00 VELOCITY= 1.00000E+01
O CONVECTIVE= 0.00000E+00 O RAOIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 0.00000E+00
RECESSION OEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN= -3.80172E-02	QRERAD= 3.80172E-02	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.86815E+03	TQRERAD= 1.41849E+02	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW= -2.80528E+01	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.76353E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 4.81000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M OOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	181.3	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	187.6	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	183.9	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	173.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	158.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	142.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	128.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	115.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	104.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	96.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	89.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	85.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	81.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	79.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	77.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	76.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	75.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCDUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.18740341E+03
0.12500000E+00	0.18513455E+03
0.25000000E+00	0.16415320E+03
0.50000000E+00	0.11256126E+03
0.10000000E+01	0.76970459E+02

PENETRATION DEPTHS (IN)

MAX OEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 OEPTH OFO.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (OEG-F) ISOTHERM= 0.00000E+00 OEPTH OFO.90000 OENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

**** TIME= 5.00000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAO= 1.00000E+00 VELOCITY= 1.00000E+01
Q CDNVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE DF ATTACK= 0.00000E+00
GAS ABLATIDN RATE= 0.00000E+00 CHAR ABLATIDN RATE= 0.00000E+00 TDTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-3.62636E-02 QRERAD= 3.62636E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQOXIO= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.86741E+03 TQRERAO= 1.42591E+02 G= 0.00000E+00
QBLDCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-2.71092E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRAOX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QDXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76353E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE ENO OF THE TIME STEP, TIME= 5.01000E+02

X (IN)	TEMPERATURE (OEG-F)	OENSITY (LB/FT3)	THETA	M OOT (LB/FT2-HR)	M CDKE (LB/FT2-HR)	MT CDKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	177.4	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	183.5	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	180.5	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	170.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	157.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	143.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	128.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	116.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	106.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	97.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	90.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	85.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	82.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	79.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	77.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	76.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	76.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)
0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.18330067E+03
0.12500000E+00	0.18153737E+03
0.25000000E+00	0.16272862E+03
0.50000000E+00	0.11364505E+03
0.10000000E+01	0.77278625E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 5.20000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-3.46876E-02 QRERAD= 3.46876E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.86670E+03 TQRERAD= 1.43300E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-2.62463E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76353E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 5.21000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	173.9	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	179.7	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	177.3	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	168.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	156.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	142.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	129.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	117.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	107.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	98.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	91.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	86.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	82.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	80.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

0.96552	78.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	77.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	76.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)
0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.17955167E+03
0.12500000E+00	0.17820279E+03
0.25000000E+00	0.16128317E+03
0.50000000E+00	0.11460580E+03
0.10000000E+01	0.77605087E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.6594DE-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 5.40000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-3.32631E-02 QRERAD= 3.32631E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QWB= 0.00000E+00 TQIN= 1.86602E+03 TQRERAD= 1.43979E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-2.54537E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76353E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 5.41000E+02

X (IN)	TEMPERATURE (OEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	170.7	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	176.3	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	174.3	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	166.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	155.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	142.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	129.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	118.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	108.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	99.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	92.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	87.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	83.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	80.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	78.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	77.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	76.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.17610822E+03
0.12500000E+00	0.17510283E+03
0.25000000E+00	0.15983322E+03
0.50000000E+00	0.11545346E+03
0.10000000E+01	0.77947250E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 5.60000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 0.00000E+00	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

QIN=-3.19671E-02	QRERAD= 3.19671E-02	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
QWB= 0.00000E+00	TQIN= 1.86537E+03	TQRERAD= 1.44631E+02	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-2.47219E+01	PL= 1.46960E+01
QSUBL= 0.00000E+00	TQRADX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.76353E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 5.61000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	167.7	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	173.1	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	171.5	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	164.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	154.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	142.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	130.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	118.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	108.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	100.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	93.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	88.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	84.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	81.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	79.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	77.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	76.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	76.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.6	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.17293181E+03

0.12500000E+00	0.17221243E+03
0.25000000E+00	0.15839281E+03
0.50000000E+00	0.11619624E+03
0.10000000E+01	0.78304260E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OFO.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OFO.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 5.80000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00	FRAD= 1.00000E+00	VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00	Q RADIATIVE= 0.00000E+00	ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00	CHAR ABLATION RATE= 0.00000E+00	TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00	RECESSION RATE= 0.00000E+00	SUBLIMATION RATE= 0.00000E+00

DIN=-3.07831E-02	QRERAD= 3.07831E-02	TQSUBL= 0.00000E+00	ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00	QSIO2= 0.00000E+00	TQOXID= 0.00000E+00	BCOF= 0.00000E+00
DWB= 0.00000E+00	TQIN= 1.86474E+03	TQRERAD= 1.45258E+02	G= 0.00000E+00
QBLOCK= 0.00000E+00	TQHW= 0.00000E+00	HTX-HW=-2.40441E+01	PL= 1.46960E+01
DSUBL= 0.00000E+00	TQRADX= 2.01000E+03	HTX= 1.29062E+02	PLPT= 1.00000E+00
QOXID= 0.00000E+00	TQBLOCK= 0.00000E+00	RHOST= 3.76353E+01	WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 5.81000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	165.0	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	170.2	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	168.9	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	162.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	153.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	141.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.41379	130.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	119.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	109.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	101.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	94.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.75862	89.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	85.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.89655	81.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	79.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	77.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	76.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	76.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.7	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.31034	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.37930	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

1.58620	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE (DEG-F)

0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTED THERMOCOUPLE LOCATIONS DEPTH - (IN), TEMPERATURE - (DEG-F)

DEPTH	TEMPERATURE
0.62500000E-01	0.16999028E+03
0.12500000E+00	0.16951106E+03
0.25000000E+00	0.15696899E+03
0.50000000E+00	0.11684436E+03
0.10000000E+01	0.78672806E+02

PENETRATION DEPTHS (IN)

MAX DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

DEPTH OF 200.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.10000 DENSITY RATIO= 0.00000E+00
DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.00000E+00 DEPTH OF0.90000 DENSITY RATIO= 0.59143E-01

EQUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

****** TIME= 6.00000E+02 TIME STEP= 1.00000E+00

FCONV= 1.00000E+00 FRAD= 1.00000E+00 VELOCITY= 1.00000E+01
Q CONVECTIVE= 0.00000E+00 Q RADIATIVE= 0.00000E+00 ANGLE OF ATTACK= 0.00000E+00
GAS ABLATION RATE= 0.00000E+00 CHAR ABLATION RATE= 0.00000E+00 TOTAL ABLATION RATE= 0.00000E+00
RECESSION DEPTH= 0.00000E+00 RECESSION RATE= 0.00000E+00 SUBLIMATION RATE= 0.00000E+00

QIN=-2.96963E-02 QRERAD= 2.96963E-02 TQSUBL= 0.00000E+00 ALPHA= 1.07123E+00
QHOT WALL= 0.00000E+00 QSIO2= 0.00000E+00 TQOXID= 0.00000E+00 BCOF= 0.00000E+00
QW8= 0.00000E+00 TQIN= 1.86414E+03 TQRERAD= 1.45863E+02 G= 0.00000E+00
QBLOCK= 0.00000E+00 TQHW= 0.00000E+00 HTX-HW=-2.34140E+01 PL= 1.46960E+01
QSUBL= 0.00000E+00 TQRADX= 2.01000E+03 HTX= 1.29062E+02 PLPT= 1.00000E+00
QOXID= 0.00000E+00 TQBLOCK= 0.00000E+00 RHOST= 3.76353E+01 WX= 1.00000E+00

TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP, TIME= 6.01000E+02

X (IN)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	THETA	M DOT (LB/FT2-HR)	M COKE (LB/FT2-HR)	MT COKE (LB/FT2-HR)	PRESSURE (PSI)
0.00000	162.4	41.64	0.3371	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.06897	167.5	83.78	0.9935	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.13793	166.4	84.19	0.9999	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.20690	160.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.27586	152.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.34483	141.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

0 41379	130.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.48276	119.9	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.55172	110.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.62069	102.3	84 20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.68965	95.5	84.20	1.0000	0.0000000E+00	0.0000000E+00	0 0000000E+00	14.6959
0.75862	90.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.82759	85.6	84.20	1.0000	0 0000000E+00	0.0000000E+00	0 D000000E+00	14.6959
0.89655	82.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
0.96552	80.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.03448	78.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.10345	77.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.17241	76.3	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.24137	75.8	84.20	1.0000	0.0000000E+00	0.0000000E+00	0 0000000E+00	14.6959
1.31034	75.4	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14 6959
1.37930	75.2	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.44827	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.51723	75.1	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.58620	75.0	84.20	1.0000	0 0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.65516	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.72413	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.79309	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.86206	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.93102	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959
1.99999	75.0	84.20	1.0000	0.0000000E+00	0.0000000E+00	0.0000000E+00	14.6959

TEMPERATURE OISTRIBUTION IN THE BACK-UP STRUCTURE (OEG-F)
0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02 0.7500000E+02
0.7500000E+02 0.7500000E+02 0.7500000E+02

TEMPERATURES AT SELECTEO THERMOCOUPLE LOCATIONS OEPTH - (IN), TEMPERATURE - (OEG-F)

OEPTH	TEMPERATURE
0.62500000E-01	0.16725691E+03
0.12500000E+00	0.16698015E+03
0.25000000E+00	0.15556956E+03
0.50000000E+00	0.11740486E+03
0.10000000E+01	0.79052475E+02

PENETRATION OEPTHS (IN)

MAX OEPTH OF 200.00 (OEG-F) ISOTHERM= 0.18996E+00
MAX DEPTH OF 400.00 (DEG-F) ISOTHERM= 0.65940E-01

OEPTH OF 200.00 (OEG-F) ISOTHERM= 0.00000E+00 DEPTH OFO.10000 OENSITY RATIO= 0.00000E+00
OEPTH OF 400.00 (OEG-F) ISOTHERM= 0.00000E+00 DEPTH OFO.90000 DENSITY RATIO= 0.59143E-01

EOUIVALENT TEST SPECIMEN LOSS= 0.02255 (IN) EQUIVALENT TEST SPECIMEN LENGTH= 1.97745 (IN)

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 MAY 1, 1983///2 INCH SLUG OF FIREX 2373///THREE AIR BACKUPS(@ 1.00")///
SAMPLE RUN OF THE ADOPTED MODEL FOR INCLUSION IN APPENDIX E OF THESIS
K(V) = .150 AT LOW TEMPS/ K(V) = .025 AT HIGH TEMPS

      *****TEMPERATURES ARE IN DEGREES F.*****

      VL = 2.000  NP = 30  INITIAL VELOCITY =    10.  INITIAL TEMPERATURE = 75.00
      EXECUTION TIME = 4.43 SEC.     NO. OF PLOT POINTS =   0


      TOTAL CONVECTIVE HEAT LOAD =      0.0 BTU   TOTAL REFERENCE LAMINAR CONVECTIVE HEAT LOAD =      0.0
      TOTAL RADIANT HEAT LOAD    =   2005.0 BTU   TOTAL REFERENCE LAMINAR RADIANT HEAT LOAD    =   2005.0
      TOTAL CONV + RAD HEAT LOAD =   2005.0 BTU   TOTAL REFERENCE LAMINAR CONV + RAD HEAT LOAD =   2005.0


      MAXIMUM REFERENCE CONVECTIVE HEAT RATE =    0.00   TIME OF MAX REF. CONV HEAT RATE =   600.0
      MAXIMUM REFERENCE RADIANT HEAT RATE    =   10.00   TIME OF MAX REF. RAD. HEAT RATE =   200.0
      MAXIMUM REFERENCE CONV + RAD HEAT RATE =   10.00   TIME OF MAX REF TOTAL HEAT RATE =   200.0


      MAXIMUM CONVECTIVE HEAT RATE =    0.00     TIME OF MAX CONVECTIVE HEAT RATE =   600.0
      MAXIMUM RADIANT HEAT RATE    =   10.00     TIME OF MAX RADIANT HEAT RATE    =   200.0
      MAXIMUM CONV + RAD HEAT RATE =    10.0     TIME OF MAX CONV + RAD HEAT RATE =   200.0

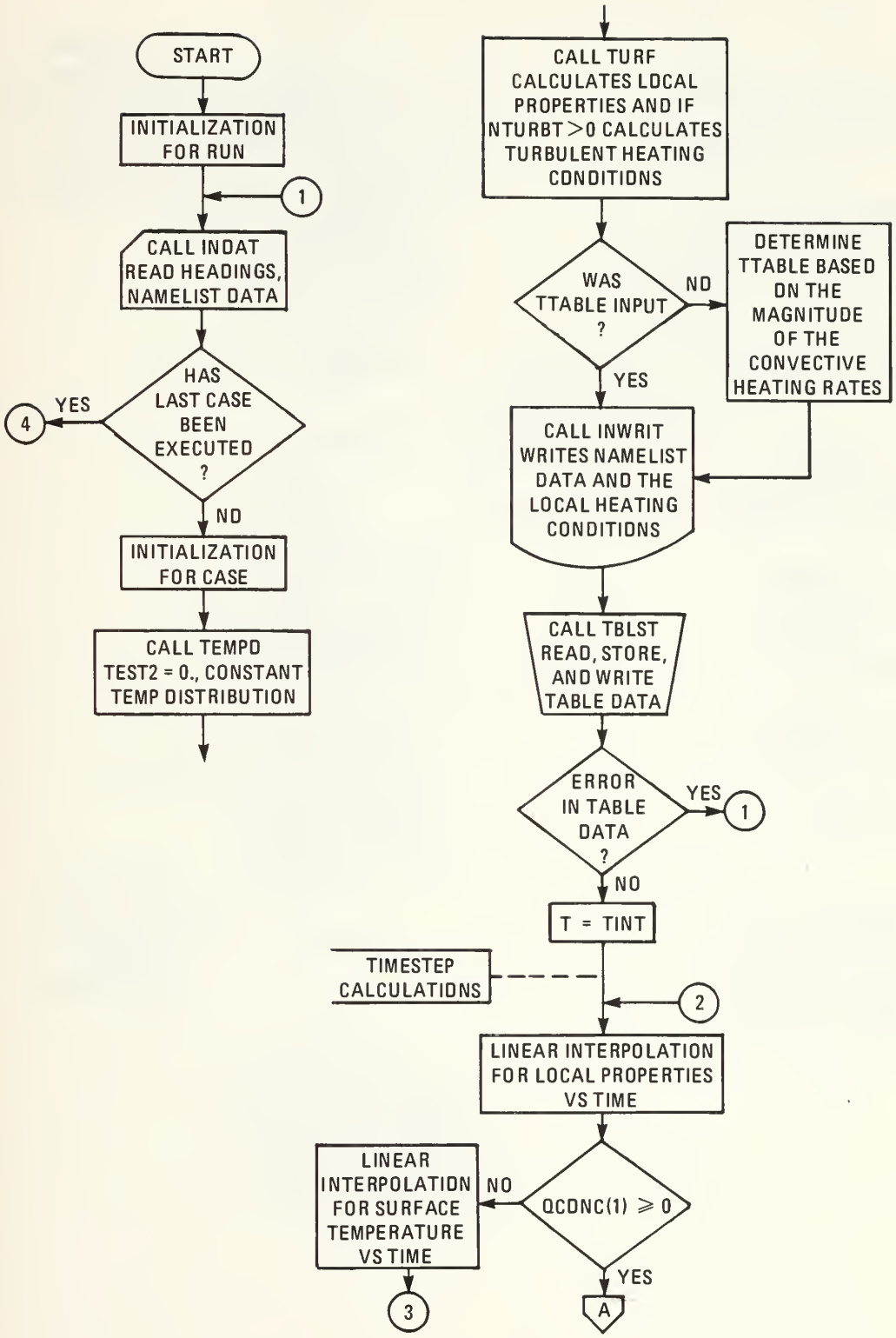

      TOTAL Q-HOT WALL =     0.00        TOTAL Q-RAD.  =  2010.00        TOTAL Q-RERAD. =   145.86
      TOTAL Q-BLOCK    =     0.00        TOTAL Q-SUBL. =     0.00        TOTAL Q-IN     =  1864.14
      TOTAL Q-COMB.    =     0.00

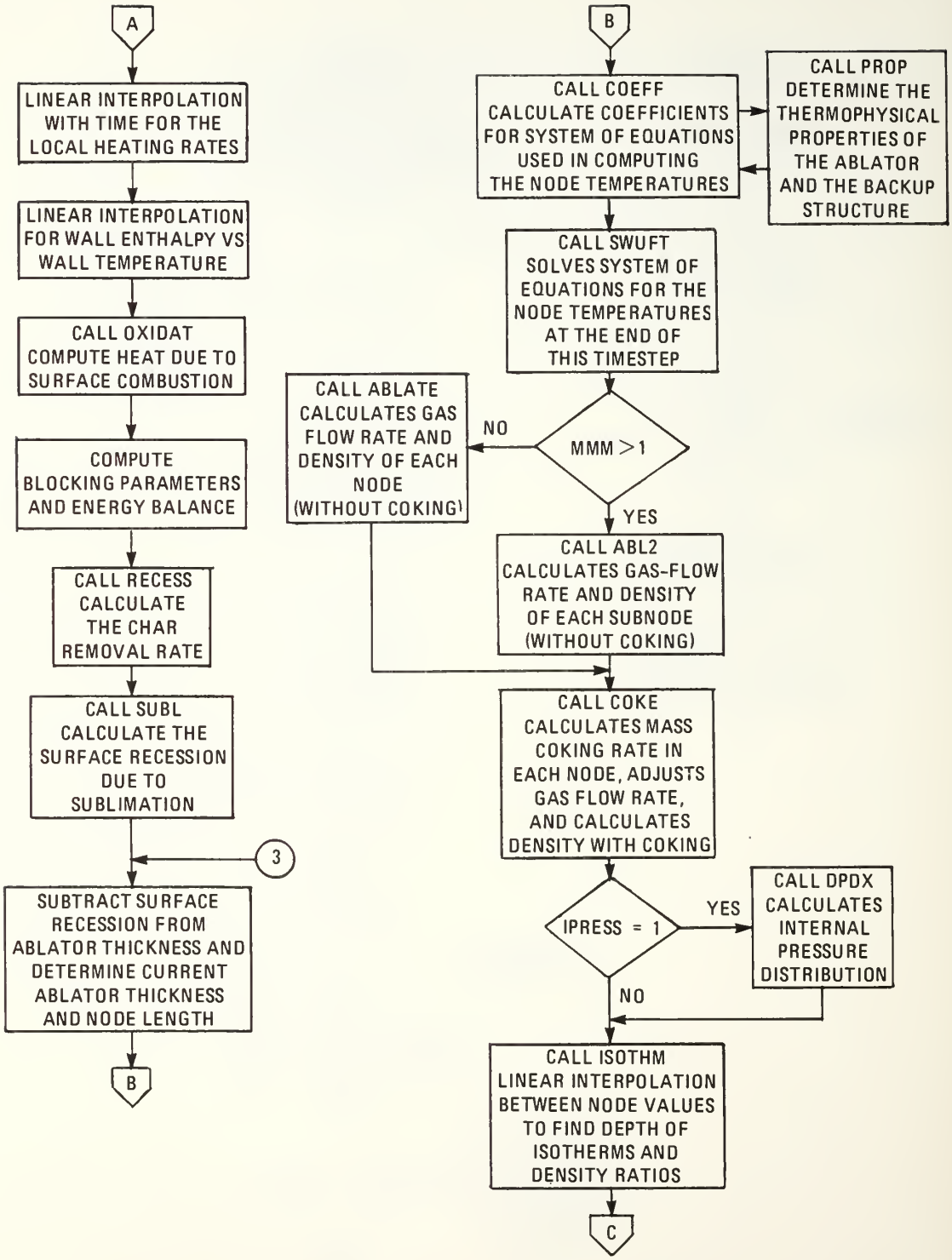

      MAXIMUM DEPTH OF  200.0 ISOTHERM =   0.190  TIME WHEN  200.0 ISOTHERM REACHED MAX DEPTH  =   280.0
      MAXIMUM DEPTH OF  400.0 ISOTHERM =   0.066  TIME WHEN  400.0 ISOTHERM REACHED MAX DEPTH  =   199.0
      MAXIMUM SURFACE TEMPERATURE      =   724.6  TIME WHEN MAX SURFACE TEMPERATURE OCCURRED  =   200.0
      MAXIMUM BONDLINE TEMPERATURE     =    75.0  TIME WHEN MAX BONDLINE TEMPERATURE OCCURRED =   601.0
      BONDLINE TEMPERATURE AT IMPACT   =    75.0                    TIME TO IMPACT            =   600.0

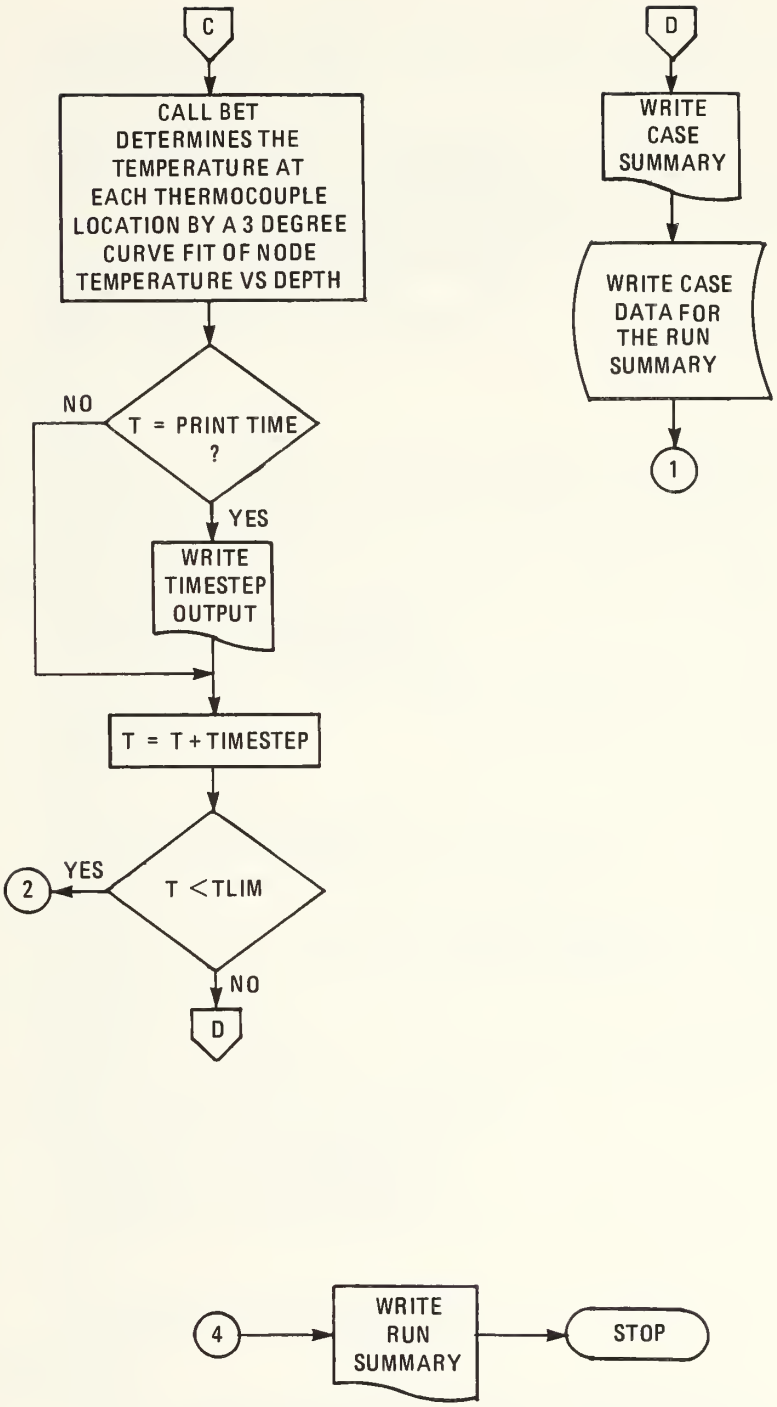

      TOTAL SURFACE RECESSION  =  0.000 IN
```

APPENDIX F

FLOWCHART


START
INITIALIZATION FOR RUN
1
CALL INDAT READ HEADINGS, NAMELIST DATA
HAS LAST CASE BEEN EXECUTED ?
YES
4
NO
INITIALIZATION FOR CASE
CALL TEMPO TEST2 = 0., CONSTANT TEMP DISTRIBUTION
CALL TURF CALCULATES LOCAL PROPERTIES AND IF NTURBT > 0 CALCULATES TURBULENT HEATING CONDITIONS
WAS TTABLE INPUT ?
NO
DETERMINE TTABLE BASED ON THE MAGNITUDE OF THE CONVECTIVE HEATING RATES
YES
CALL INWRIT WRITES NAMELIST DATA AND THE LOCAL HEATING CONDITIONS
CALL TBLST READ, STORE, AND WRITE TABLE DATA
ERROR IN TABLE DATA ?
YES
1
NO
T = TINT
TIMESTEP CALCULATIONS
2
LINEAR INTERPOLATION FOR LOCAL PROPERTIES VS TIME
QCONC(1) ≥ 0
NO
LINEAR INTERPOLATION FOR SURFACE TEMPERATURE VS TIME
3
YES
A


A
LINEAR INTERPOLATION WITH TIME FOR THE LOCAL HEATING RATES
LINEAR INTERPOLATION FOR WALL ENTHALPY VS WALL TEMPERATURE
CALL OXIDAT COMPUTE HEAT DUE TO SURFACE COMBUSTION
COMPUTE BLOCKING PARAMETERS AND ENERGY BALANCE
CALL RECESS CALCULATE THE CHAR REMOVAL RATE
CALL SUBL CALCULATE THE SURFACE RECESSION DUE TO SUBLIMATION
3
SUBTRACT SURFACE RECESSION FROM ABLATOR THICKNESS AND DETERMINE CURRENT ABLATOR THICKNESS AND NODE LENGTH
B
B
CALL COEFF CALCULATE COEFFICIENTS FOR SYSTEM OF EQUATIONS USED IN COMPUTING THE NODE TEMPERATURES
CALL PROP DETERMINE THE THERMOPHYSICAL PROPERTIES OF THE ABLATOR AND THE BACKUP STRUCTURE
CALL SWUFT SOLVES SYSTEM OF EQUATIONS FOR THE NODE TEMPERATURES AT THE END OF THIS TIMESTEP
MMM > 1
NO
CALL ABLATE CALCULATES GAS FLOW RATE AND DENSITY OF EACH NODE (WITHOUT COKING)
YES
CALL ABL2 CALCULATES GAS-FLOW RATE AND DENSITY OF EACH SUBNODE (WITHOUT COKING)
CALL COKE CALCULATES MASS COKING RATE IN EACH NODE, ADJUSTS GAS FLOW RATE, AND CALCULATES DENSITY WITH COKING
IPRESS = 1
YES
CALL DPDX CALCULATES INTERNAL PRESSURE DISTRIBUTION
NO
CALL ISOTHM LINEAR INTERPOLATION BETWEEN NODE VALUES TO FIND DEPTH OF ISOTHERMS AND DENSITY RATIOS
C


C
CALL BET DETERMINES THE TEMPERATURE AT EACH THERMOCOUPLE LOCATION BY A 3 DEGREE CURVE FIT OF NODE TEMPERATURE VS DEPTH
NO
T = PRINT TIME ?
YES
WRITE TIMESTEP OUTPUT
T = T + TIMESTEP
2
YES
T < TLIM
NO
D
D
WRITE CASE SUMMARY
WRITE CASE DATA FOR THE RUN SUMMARY
1
4
WRITE RUN SUMMARY
STOP

APPENDIX G

PROGRAM LISTING

```
C      THIS SUBROUTINE OETERMINES THE MASS FLOW RATE FROM THE
C        ABLATING NOOES
       SUBROUTINE ABLATE(XV,JENO)
C
       OIMENSION XV(1)
       COMMON /ABPROP/ RHO(50)
       COMMON /TEMPS/ TEMOI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
      1      , TUL2(50),TY(200),TEMPI,TXO,SURTEM
       COMMON /ABLATS/ XMOG(50),TABL,TCHAR,RHOV,RHOC,TREC,XLOST,SOOTOS
      1      , SOOT,XMOC,XMT
       COMMON /INOIX/ NP,NP2,IFPT,NPBS,NPF,NMB
       COMMON /TIMES/ TINT,TLIM,T,OT
       COMMON /HSPARA/ OX,     TL,VL,BL,OMP,VPT
       COMMON /ARRH/ THETA(50),AP,XB,SN,CA
       OO 300 I=1,NP
  300  TUL1(I)=TUL2(I)
       XNP=NP
       KI=NP
       KI1=NP-1
       IF(TX2(NP).GE.TABL)TUL2(NP)=TUL1(NP)-AP*OT*EXP(-XB/TX2(NP))
       IF(SN.EO.1.)GO TO 303
       RHO(NP)=RHOC+(RHOV-RHOC)*((1.-SN)*TUL2(NP))**(1./(1.-SN))
       GO TO 304
  303  RHO(NP)=RHOC+(RHOV-RHOC)*EXP(TUL2(NP))
  304  CONTINUE
       THETA(NP)=(RHO(NP)-RHOC)/(RHOV-RHOC)
       IF(THETA(NP).LE..01)RHO(NP)=RHOC
       IF(THETA(NP).GT.0.99) JENO=NP-1
        IF(THET A(NP).GT.1.0)RHO(NP)=RHOV
       XMT=0.
       XMOG(NP)=XMT
       OO 310 I=1,KI1
       KI=NP-I
       ZKI=KI
       IF(TX2(KI).GE.TABL)GO TO 3040
       IF(SOOT.EO.0.)GO TO 3048
       TUL2(KI)=(TUL1(KI)+SOOT*OT/OX*(XNP-ZKI)/(XNP-1.)
      1*TUL2(KI+1))/(1.+SOOT*OT/OX*(XNP-ZKI)/(XNP-1.))
       GO TO 3048
 3040  CONTINUE
       TUL2(KI)=(TUL1(KI)-AP*OT*EXP(-XB/TX2(KI))+SOOT*OT/OX
      1*(XNP-ZKI)/(XNP-1.)*TUL2(KI+1))/(1.+SOOT*OT/OX*
      2(XNP-ZKI)/(XNP-1.))
 3048  CONTINUE
       IF(SN.EO.1.)GO TO 305
       RHO(KI)=RHOC+(RHOV-RHOC)*((1.-SN)*TUL2(KI))**(1./(1.-SN))
       GO TO 307
  305  RHO(KI)=RHOC+(RHOV-RHOC)*EXP(TUL2(KI))
  307  THETA(KI)=(RHO(KI)-RHOC)/(RHOV-RHOC)
       IF(THETA(KI).LE..01)RHO(KI)=RHOC
       IF(THETA(KI).GT.0.99) JENO=KI-1
       IF(THETA(KI).GT.1.0)RHO(KI)=RHOV
       IF(TX2(KI).LT.TABL)GO TO 308
       AVEFAC = .5
       F1=1.0
       IF( THETA(KI) .LT.0.01) GO TO 3075
       IF(TX2(KI+1) .LT. TABL)  AVEFAC=1.0
       GO TO 3076
 3075  F1=0.0
 3076  CONTINUE
       XMT =XMT +CA*OX*(AVEFAC*(RHO(KI)-RHOC)**SN*EXP(-XB/TX2(KI))
      1      +(1.-AVEFAC)*(RHO(KI+1)-RHOC)**SN*EXP(-XB/TX2(KI+1)))
      2 *F1
  308 XMOG(KI)=XMT
  310  CONTINUE
       RETURN
       ENO
```

```
C
C      THIS SUBROUTINE OETERMINES THE MASS FLOW RATE FROM THE ABLATING
C      NOOES USING NOOAL SUBOIVISION TO INSURE UNIFORM GAS PROOUCTION
C      THE NUMBER OF SUBOIVISIONS MUST BE AN EVEN NUMBER NOT TO EXCEEO
C      TWENTY
C
       SUBROUTINE ABL2(TUL2,TX2,NP,NPI,RHOC,RHOV,SN,SOOT,OT,OX,AP,XB,CA,
      1XMOGI,THETI,RHOI,MMM,OMP,TABL,TABL2,JENO,IENTER)
C
       OIMENSION TUL2(500),TX2(500),TUL1(500),THETA(500),RHO(500),
      1          XMOG(500),XMOGI(50),THETI(50),RHOI(50)
       IF(NP.LE.500) GO TO 250
       WRITE(20,200) NP
  200 FORMAT(6X14HERROR NP*MMM =I5,30H, NP*MMM MUST BE LESS THAN 500)
       STOP
C
  250 00 300 I=1,NP
  300  TUL1(I)=TUL2(I)
       IENTER=0
       XNP=NP
       KI=NP
       KI1=NP-1
       IF(TX2(NP).GE.TABL)TUL2(NP)=TUL1(NP)-AP*OT*EXP(-XB/TX2(NP))
       IF(SN.EQ.1.)GO TO 303
       RHO(NP)=RHOC+(RHOV-RHOC)*((1.-SN)*TUL2(NP))**(1./(1.-SN))
       GO TO 304
  303  RHO(NP)=RHOC+(RHOV-RHOC)*EXP(TUL2(NP))
  304  CONTINUE
       THETA(NP)=(RHO(NP)-RHOC)/(RHOV-RHOC)
       IF(THETA(NP).LE..01)RHO(NP)=RHOC
       IF(THETA(NP).GT.1.0) RHO(NP)=RHOV
       IF(TX2(NP).GE.TABL2) IENTER=1
       XMT=0.
       XMOG(NP)=XMT
       00 310 I=1,KI1
       KI=NP-I
       ZKI=KI
       IF(TX2(KI).GE.TABL)GO TO 3040
       IF(SOOT.EQ.0.)GO TO 3048
       TUL2(KI)=(TUL1(KI)+SOOT*OT/OX*(XNP-ZKI)/(XNP-1.)
      1*TUL2(KI+1))/(1.+SOOT*OT/OX*(XNP-ZKI)/(XNP-1.))
       GO TO 3048
 3040 CONTINUE
       TUL2(KI)=(TUL1(KI)-AP*OT*EXP(-XB/TX2(KI))+SOOT*OT/OX
      1*(XNP-ZKI)/(XNP-1.)*TUL2(KI+1))/(1.+SOOT*OT/OX*
      2(XNP-ZKI)/(XNP-1.))
 3048 CONTINUE
       IF(SN.EQ.1.)GO TO 305
       RHO(KI)=RHOC+(RHOV-RHOC)*((1.-SN)*TUL2(KI))**(1./(1.-SN))
       GO TO 307
  305  RHO(KI)=RHOC+(RHOV-RHOC)*EXP(TUL2(KI))
  307  THETA(KI)=(RHO(KI)-RHOC)/(RHOV-RHOC)
       IF(THETA(KI).LE..01)RHO(KI)=RHOC
       IF(THETA(KI).GT.1.0)RHO(KI)=RHOV
       IF(TX2(KI).GE.TABL2) IENTER=1
```

```
      IF(TX2(KI).LT.TABL)GO TO 308
      XMT=XMT+CA*OX/2.*((RHO(KI)-RHOC)**SN*EXP(-XB/TX2(KI))
     1+(RHO(KI+1)-RHOC)**SN*EXP(-XB/TX2(KI+1)))
  308 XMOG(KI)=XMT
  310 CONTINUE
      IF(OMP) 350,350,320
  320 WRITE(20,325) (TX2(I),RHO(I),XMOG(I),THETA(I),TUL2(I),TUL1(I),
     1I,I=1,NP)
  325 FORMAT(/4X,6HTX2(I),7X,6HRHO(I),7X,7HXMOG(I),5X,8HTHETA(I),6X,
     17HTUL2(I),6X,7HTUL1(I),7X,1HI/6(1X,1PE12.5),I6)
  350 L=1
      K=MMM/2+1
      DO 2000 I=1,NPI
      THETI(I)=0.
      RHOI(I)=0.
      XMDGI(I)=XMOG(L)
      DO 1000 J=L,K
      THETI(I)=THETI(I)+THETA(J)
      RHOI(I)=RHOI(I)+RHO(J)
 1000 CONTINUE
      THETI(I)=THETI(I)/FLOAT(K-L+1)
      IF(THETI(I).LT.0.99) JENO=I
      RHOI(I)=RHOI(I)/FLOAT(K-L+1)
      L=K+1
      K=L+MMM-1
      IF(I.EQ.(NPI-1)) K=NP
 2000 CONTINUE
      IF(DMP) 2050,2050,2010
 2010 WRITE(20,2020) (THETI(L),RHOI(L),XMOGI(L),L,L=1,NPI)
 2020 FORMAT(/3X,8HTHETI(L),6X,7HRHOI(L),5X,8HXMOGI(L),7X,1HL/
     113(1X,1PE12.5),I6)
 2050 RETURN
      END
```

```
      SUBROUTINE ATMOS(OPTION,H,HMAX,ANS)
      OIMENSION ANS(16),A(64)
      OATA (A(I),I=1,64)/        2116.1321,518.67,2.37689E-3,1116.4,
     .                           32.174,518.67,28.964,3.7371342E-7,
     .                           2116.13210,539.37,2.266704E-3,1138.496,
     .                           32.09870,539.37,28.964,3.8512E-7,
     .                           2116.65421,542.07,2.252326E-3,1141.278,
     .                           32.12966,542.07,28.964,3.8664E-7,
     .                           2132.31766,516.87,2.39533E-3,1114.4973,
     .                           32.12966,516.87,28.964,3.7269E-7,
     .                           2116.6542,529.47,2.31605E-3,1128.00285,
     .                           32.17366,529.47,28.964,3.79718E-7,
     .                           2126.05228,489.87,2.527843E-3,
     .                           1084.99763,32.17366,489.87,28.964,
     .                           3.56009E-7,2109.34460,516.87,2.37007E-3
     .                           ,1114.49727,32.21450,516.87,28.964,
     .                           3.72693E-7,2116.65420,462.87,
     .                           2.666379E-3,1054.67307,32.21450,462.87,
     .                           28.964,3.41620E-7/
      INTEGER OPTION
      FLTM52=0.
      FLTM53=0.
      IF(OPTION.EO.0) OPTION=1
      IF(H-HMAX) 50,50,25
 25   ZERO = 0.
      CALL ATMOS3(H,ZERO,ANS)
C     ***********
      K=0
      GO TO 110
   50 GO TO(25,55,60,65,70,75,80,85,65,65),OPTION
   55 K=8
      GO TO 100
   60 K=16
      GO TO 100
   65 K=24
      GO TO 100
   70 K=32
       GO TO 100
   75 K=40
      GO TO 100
   80 K=48
      GO TO 100
   85 K=56
  100 CALL ATSEAS(H,HMAX,OPTION,ANS)
C     ***********
  110 CONTINUE
      OO 115 I=9,16
      ANS(I)=ANS(I-8)*A(K+1)
  115 K=K+1
C     LINEAR OEVIATION FACTOR
  120 ANS(3)=ANS(3)*(1.+FLTM52)
C     EXPONENTIAL OEVIATION FACTOR
      IF(FLTM53-0.0) 125,125,130
  130 CONTINUE
      ANS(3)=ANS(3)*(1.+FLTM53 *EXP(5.614416E-6*H))
  125 CONTINUE
      RETURN
      ENO
```

```
      SUBROUTINE ATMOS3(ZZ,ZMAX,ANSW)
C
C
C THE PURPOSE OF ATMOS3 IS TO COMPUTE THE ATMOSPHERIC OENSITY ANO
C SPEEO OF SOUNO AS A FUNCTION OF ALTITUOE. THE USER MAY CHOOSE THE
C STANOARO ATMOSPHERE OR ANY ONE OF 6 SUPPLEMENTAL ATMOSPHERES.
C
C
C
      OIMENSION HB(10),ZB(14),TMB(24),ALP1(24),GB(14)
      DIMENSION ANSW(16)
      OATA OUM,OUM1,OUM2,OUM3/28.9644,.10325E6,288.16,9.80665/
      Z=ZZ
      IF(ZMAX)1010,1010,1000
 1000 CONTINUE
      IF(Z.GT.ZMAX) GO TO 1300
 1010 Z=Z*.304800612
      IF(Z.GT.1400000.) GO TO 1300
      DATA(HB(I),I=1,10)/-5000.0,0.0,11000.0,20000.0,32000.0,47000.0,
     152000.0,61000.0,79000.0,88743.0/
      OATA(ZB(I),I=1,14)/90000.0,100000.0,110000.0,120000.0,150000.0,16
     10000.0,170000.0,190000.0,230000.0,300000.0,400000.0,500000.0,60000
     20.0,700000.0/
      OATA(TMB(I),I=1,24)/320.65,288.15,216.65,216.65,228.65,270.65,
     1270.65,252.65,180.65,180.65,180.65,210.65,260.65,360.65,
     2960.65,1110.65,1210.65,1350.65,1550.65,1830.65,2160.65,
     32420.65,2590.65,2700.65/
      OATA(ALP1(I),I=1,24) / 12.087778,11.526088,10.027120,8.6079235,
     16.7662077,4.7086738,4.0775458,2.9019653,.37006732E-1,-1.8055744,
     2-1.8055744,-3.5040610,-4.9124564,-5.9828218,-7.5886378,-7.9035491,
     3-8.1833670,-8.6884559,-9.5726883,-10.879634,-12.421644,-13.724116,
     4-14.879663,-15.942630/
      OATA(GB(I),I=1,14)/9.535,9.505,9.476,9.447,9.360,9.331,9.302,
     19.246,9.134,8.942,8.679,8.428,8.187,7.956/
 1020 G =(((((-5.5905936E-33)*Z+2.972462E-26)*Z-1.5167771E-19)*Z+7.25394
     155E-13)*Z-3.0854195E-6)*Z+9.80665
 1030 H=((((((-9.5013649E-35*Z)+6.0621354E-28)*Z-3.8667054E-21)*Z+
     12.4656553E-14)*Z-1.5731262E-7)*Z+1.0)*Z
      IF (Z-90000.0)1035,1035,1150
 1035 IF (Z)1050,1040,1080
 1040 N=2
      GO TO 1070
 1050 IF(Z+5000.0) 1300,1060,1060
 1060 N=1
      GO TO 1110
 1070 AL=0.0
      GO TO 1120
 1080 OO 1090 N=3,10
      IF(H-HB(N)) 1100,1070,1090
 1090 CONTINUE
      N=9
      GO TO 1070
 1100 N=N-1
 1110 AL=(TMB(N+1)-TMB(N))/(HB(N+1)-HB(N))
 1120 TMA = TMB(N) + AL*(H - HB(N))
```

```
      IF(AL) 1130,1140,1130
1130  ALPP=ALP1(N)-3.41631947E-2*ALOG((AL*(H-HB(N))+TMB(N))/TMB(N))/AL
      GO TO 1240
1140  ALPP=ALP1(N)-3.41631947E-2*(H-HB(N))/TMB(N)
      GO TO 1240
1150  IF(Z-700000.0) 1170,1160,1160
1160  M1=14
      N=24
      GO TO 1210
1170  DO 1180 M1=2,14
      IF(Z-ZB(M1)) 1190,1200,1180
1180  CONTINUE
1190  M1=M1-1
1200  N=M1+10
1210  AL=(TMB(N+1)-TMB(N))/(ZB(M1+1)-ZB(M1))
      GG=(G+GB(M1))/2.0
      TMA = TMB(N) + AL*(Z - ZB(M1))
      IF(AL ) 1220,1230,1220
1220  ALPP=ALP1(N)-3.48367635E-3*GG*ALOG((Z-ZB(M1)+TMB(N)/AL)*AL/TMB(N))
     1/AL
      GO TO 1240
1230  ALPP=ALP1(N)-3.48367635E-3*GG*(Z-ZB(M1))/TMB(N)
1240  P=EXP(ALPP)
1245  RHO = 2.84381743E-3*P/TMA
1246  CONTINUE
      IF(Z-90000.0) 1250,1250,1260
1250  WM=28.9644
      CS = .589102444E-1*TMA**.5
      T = TMA*WM/OUM
      XMU=8.14785279E-2*T**1.5/(T+110.4)
      GO TO 1310
1260  CS      =.791785926
      XMU=6.7974E-1
      Z=Z*1.E-3
      IF(Z-169.5) 1270,1280,1280
1270  WM= (((((((.10923927E-13*Z-.11006185E-10)*Z+.49584323E-8)*Z-.13071
     1742E-5)*Z+.22007775E-3)*Z-.24083631E-1)*Z+.16586041E1)*Z-.65156805
     2E2)*Z+1139.0647
      GO TO 1290
1280  WM= ((((((-.21764045E-18*Z+.18921597E-14)*Z-.43903233E-11)*Z+.4509
     16184E-8)*Z-.23285059E-5)*Z+.63311551E-3)*Z-.11575533)*Z+36.084062
1290  T= TMA*WM/OUM
      Z=Z*1.E3
      GO TO 1310
1300  T=0.0
      TMA = 0.
      P=0.0
      RHO = .1E-30
      G=0.0
      WM=0.0
      CS      =.791785926
      XMU=0.0
1310  ANSW(1)=P/OUM1
      ANSW(2)=T/OUM2
      ANSW(3)=RHO
      ANSW(4)=CS
      ANSW(5)=G/OUM3
      ANSW(6) = TMA/OUM2
      ANSW(7)=WM
      ANSW(8)=XMU
      RETURN
       END
```

```
      SUBROUTINE ATSEAS(H,HMAX,JJ,ANS)
      COMMON / ATBD /    DARAY(472)
      DIMENSION ANS(16),CON(13),GSLG(9)
      DIMENSION ERAD(10)
      DATA (ERAD(I),I=2,10)/6339752.,6344206.,6344206.,6356766.,
     *6356766.,6368186.6,6368186.,6344206.,6344206./
      DATA (CON(I),I=1,13)/.3048,6356766.,0.341624,28.964,2.2E5,
     *  4.7750E4,5.7129668,22.,1.8E5,2.97791E5,9.93169355,25.9700156,
     *  110.4/,(GSLG(I),I=1,9)/99767097,.99863251,.99863256,1.0,1.0,
     *  1.0012706,1.0012706,.99863256,.99863256/,HTST1/9.0E4/,
     *  HST2/1.8E5/
      CALL BDAT(JJ-1)
C     *********
      IF(JJ.LT.9) GO TO 5
      LROW=JJ-1
      INDX1=118
      INDX2=236
      INDX3=354
      INDSL2=238
      INDSL3=356
      ITOP = 118
      GO TO 901
    5 LROW=JJ-1
      INDX1=23
      INOX2=46
      INDX3=69
      INDSL2=48
      INDSL3=71
      GO TO (6,7,7,7,8,8,7),LROW
    6 ITOP = 21
      GO TO 901
    7 ITOP = 23
      GO TO 901
    8 ITOP = 22
  901 SAVE = H
      SV1 = H * 0.3048
      IF(HMAX) 10,39,10
   10 IF(HMAX - H) 20,39,39
   20 DO 30 JK = 1,8
   30 ANS(JK) = 0.0
      ANS(4) = 0.791785926
      RETURN
   39 CONTINUE
   40 SV2=SV1+ERAD(JJ)
      SV2=ERAD(JJ)/SV2
      HG = SV2 * SV1 * GSLG(LROW)
      ANS(5) = SV2 * SV2
      INOX = 0
      DO 60 JL = 1,ITOP
      IF(HG-DARAY(JL)) 50,70,60
   50 INOX = JL - 1
      GO TO 70
   60 CONTINUE
   70 SV2=HG-DARAY(INDX)
      SAVE=SV2*DARAY(INOX+INDX1)+DARAY(INDX+INDX2)
```

```
      IF(DARAY(INDX+INDX1)) 80,90,80
   80 X=ALOG(DARAY(INDX+INDX2)/SAVE)
      Y=X/DARAY(INDX+INDX1)
      GO TO 100
   90 Y=-SV2/DARAY(INDX+INDX2)
  100 Z = Y * CON(3)
      ZX=EXP(Z)*DARAY(INDX+INDX3)
      ANS(1)=ZX/DARAY(INDSL3)
      ANS(3)=ANS(1)*DARAY(INDSL2)/SAVE
      ANS(6)=SAVE/DARAY(INDSL2)
      ANS(4)=SQRT(ANS(6))
      IF(HG - HTST1) 110,110,120
  110 ANS(7) = CON(4)
      GO TO 160
  120 IF(HG - HTST2) 140,140,150
  140 X = (HG - CON(5)) / CON(6)
      Y = ATAN(X)
      ANS(7) = -(Y * CON(7)) + CON(8)
      GO TO 160
  150 X = (HG - CON(9)) / CON(10)
      Y = ATAN(X)
      ANS(7) = -(Y * CON(11)) + CON(12)
  160 SAVEX = ANS(7) / CON(4) * SAVE
      ANS(2)=SAVEX/DARAY(INDSL2)
      SV2 = SQRT(ANS(2)**3)
      SAVEX = SAVEX + CON(13)
      ANS(8)=((DARAY(INDSL2)+CON(13))/SAVEX)*SV2
      RETURN
      END
```

```
 SUBROUTINE BDAT(J)
 COMMON /ATBD/ DARAY(472)
 DIMENSION D(472,9)
 DATA (D(I,1),I=1,23)      /-5.0E3,0.,2.25E3,2.5E3,1.65E4,2.2E4,4.7E
14,5.1E4,5.9E4,7.9E4,8.8533E4,8.8743E4,9.8541E4,1.08129E5,1.17776E5
2,1.46541E5,1.56071E5,1.65571E5,1.84485E5,1.93898E5,1.0E10,0.,0./
 DATA (D(I,1),I=24,46)    /-.006,-.006,.0032,-.0067,.004,.0022,0.,-0
1.002,-.0035,0.,-.01666,.00309,.00516,.01306,.02085,.01573977,.0105
226316,.007401925,.005311803,.005336895,.005336895,0.,0./
 DATA (D(I,1),I=47,69)    /329.65,299.65,286.15,286.95,193.15,215.10
15,270.15,270.15,254.15,184.15,184.15,180.65,210.65,260.65,360.65,9
260.65,1110.65,1210.65,1350.65,1400.65,1400.65,0.,0./
 DATA (D(I,1),I=70,92)    /3641.9517,2116.1321,1630.77399,1583.26150
1,210.5854,83.805723,2.4434982,1.4734921,5.1931646E-1,2.2371584E-2,
23.816034E-3,3.43301E-3,6.28104E-4,1.535937E-4,5.2664696E-5,1.05723
3730E-5,7.71628440E-6,5.83290360E-6,3.51987720E-6,2.78611690E-6,2.7
48611690E-6,0.,0./
 DATA (D(I,2),I=1,23)     /-5.0E3,0.,1.E3,6000.,1.5E4,1.6E4,2.1E4,3.
12E4,4.7E4,5.1E4,5.9E4,7.9E4,88620.,88743.,98451.,108129.,117776.,
2146541.,156071.,165571.,184485.,193898.,1.0E10/
 DATA (D(I,2),I=24,46)     /-.0075,-.0075,-.0055,-.007,0.,.0022,.002
1,.0024,0.,-.002,-.0038,0.,.00406,.00309,.00516,.01036,.02085,.0157
2397691,.010526316,.007401925,.005311803,.005336895,.005336895/
 DATA (D(I,2),I=47,69)     /338.65,301.15,293.65,266.15,203.15,203.1
15,214.15,236.15,272.15,272.15,256.15,2*180.15,180.65,210.65,260.65
2,360.65,960.65,1110.65,1210.65,1350.65,2*1400.65/
 DATA (D(I,2),I=70,92)      /36114270.5E-4,21166542.1E-4,18888658.80
1E-4,10275849.7E-4,2750501.8E-4,232487.4E-3,1025057.9E-4,192883.9E-
24,2559407.7E-6,15490525.5E-7,5.5026744E-1,2.324445E-2,3.7498299E-3
3,3.43301E-3,6.28104E-4,1.535937E-4,5.2664696E-5,1.0572373E-5,7.716
42844E-6,5.8329036E-6,3.5198772E-6,2.7861169E-6,2.7861169E-6 /
 DATA (D(I,3),I=1,23)       /-5.E3,0.,2.E3,1.2E4,1.7E4,1.8E4,2.2E4,
13.2E4,4.7E4,5.1E4,5.9E4,7.9E4,8.862E4,88743.,98451.,108129.,117776
2.,146541.,156071.,165571.,184485.,193898.,1.E10/
 DATA (D(I,3),I=24,46)       /2*-.003,-.0065,-.0026,0.,.0025,.002,
1.0024,0.,-.002,-.0031,0.,-.0853658,.00309,.00516,.01036,.02085,
2.01573977,.010526316,.007401925,.005311803,2*.005336895/
 DATA (D(I,3),I=47,69)       /302.15,287.15,281.15,216.15,2*203.15,
1213.15,233.15,2*269.15,253.15,2*191.15,180.65,210.65,260.65,360.65
2,960.65,1110.65,1210.65,1350.65,1400.65,0./
 DATA (D(I,3),I=70,92)       /3803.55380284,2132.31766,1678.056725,
1421.66007,186.6394,157.7497,81.80707,17.678814,2.289787,1.378112,
2.48377087,.02188288,3.9208748E-3,3.43301E-3,6.28104E-4,1.535937E-4
3,5.2664696E-5,1.0572373E-5,7.7162844E-6,5.8329036E-6,3.5198772E-6,
42*2.7861169E-6/
 DATA (D(I,4),I=1,23)      /-5.0E3,0.,2.0E3,6.0E3,1.3E4,1.7E4,2.7E4,
13.2E4,4.7E4,5.2E4,6.2E4,7.9E4,88743.,89229.,98451.,108129.,117776.
2,146541.,156071.,165571.,184485.,193898.,1.0E10/
 DATA (D(I,4),I=24,46)     /2*-.0045,-.006,-.0065,0.,.0012,.0021,
1.0025,0.,-.0025,-.0045,0.,.01646,3.09E-3,5.16E-3,1.036E-2,2.085E-2
2,1.5739769E-2,.010526316,7.401925E-3,5.311803E-3,2*5.336895E-3/
 DATA (D(I,4),I=47,69)     /316.65,294.15,285.15,261.15,2*215.65,
1227.65,238.15,2*275.65,250.65,2*174.15,182.15,210.65,260.65,360.65
2,1.5739769E-2,.01052632,7.401925E-3,5.311803E-3,2*5.336895E-3/
 DATA (D(I,4),I=70,92)     /3701.5408,2116.6542,1672.9609,1015.51367
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15,371.34907,197.05247,42.172273,20.250961,2.7452807,1.4772721,
2    4.02905703E-1,2.53852313E-2,3.75400685E-3,3.13269E-3,6.28104E-4
3,1.535937E-4,5.2664696E-5,1.0572373E-5,7.7162844E-6,5.8329036E-6,
43.5198772E-6,2*2.7861169E-6/
 DATA (D(I,5),I=1,23) /-5.0E3,0.,3.0E3,1.0E4,1.9E4,2.7E4,3.2E4,
14.7E4,5.2E4,6.4E4,7.9E4,88743.,89229.,98451.,108129.,117776.,14654
21.,156071.,165571.,184485.,193898.,1.0E10,0./
 DATA (D(I,5),I=24,46) / -.0035,-.0035,
X-.006,-.0005,0...0008,.0031,0.,
1-.002,-.0021,0.,-.05864,3.09E-3,5.16E-3,1.036E-2,2.085E-2,.0157397
269,1.0526316E-2,7.401925E-3,5.311803E-3,2*5.336895E-3,0./
 DATA (D(I,5),I=47,69) /289.65,272.15,261.65,219.65,2*215.15,
1219.15,2*265.65,241.65,2*210.15,182.15,210.65,260.65,360.65,960.65
2,1110.65,1210.65,1350.65,2*1400.65,0./
 DATA (D(I,5),I=70,92)     /3907.16954,2126.05228,1448.7020482,535.0
163452,130.06511188,36.51463464,16.627483136,1.994688146,1.04861576
26,2.08052385E-1,2.144639574E-2,4.400385E-3,3.13269E-3,6.28104E-4,
31.535937E-4,5.2664696E-5,1.0572373E-5,7.7162844E-6,5.8329036E-6,
43.5198772E-6,2*2.7861169E-6,0./
 DATA (D(I,6),I=1,23)/-5.0E+3,0.,5.0E3,1.0E4,2.3E4,3.2E4,4.3E4,
14.8E4,5.3E4,5.9E4,7.9E4,88858.,89229.,98451.,108129.,117776.,14654
21.,156071.,165571.,184485.,193898.,1.0E10,0./
 DATA (D(I,6),I=24,46)/2*-.0054,-.0070,0.,.0015,.0030,.0011,0.,
1-.0020,-.0047,0.,.02965,.00309,.00516,-01036,.02085,.15739769E-1,
2.10526316E-1,.7401925E-2,.5311803E-2,2*.5336895E-2,0./
 DATA (D(I,6),I=47,69)/314.15,287.15,260.15,2*225.15,238.65,
1271.65,2*277.15,265.15,2*171.15,182.15,210.65,260.65,360.65,960.65
2,1110.65,1210.65,1350.65,2*1400.65,0./
 DATA (D(I,6),I=70,92)     /3279.7498,2109.3446,1130.984628,558.8301
13,77.796958,20.6513190,4.7249319,2.5353904,1.368881107,.642681796,
2.0266738111,3.7281099E-3,3.13269E-3,6.28104E-4,1.535937E-4,5.26646
396E-5,1.0572373E-5,7.7162844E-6,5.8329036E-6,3.5198772E-6,2*2.7861
4169E-6,0./
 DATA (D(I,7),I=1,23) /-5.0E3,0.,1.E3,3.5E3,8.5E3,1.5E4,2.5E4,
13.4E4,5.E4,5.4E4,5.9E4,6.9E4,88858.,89229.,98451.,108129.,117776.,
2146541.,156071.,165571.,184485.,193898.,1.E10/
 DATA (D(I,7),I=24,46)  /  2*.002,-.0032,-.0068,0.,-.0006,.001,.002
15,0.,-.0018,-.0005,-.0014,-.09757,.00309,.00516,.01036,.02085,
2.157397691E-1,.10526316E-1,.7401925E-2,.5311803E-2,2*.5336895E-2/
 DATA (D(I,7),I=47,69) /247.15,257.15,259.15,251.15,2*217.15,
1211.15,220.15,2*260.15,251.15,246.15,218.3488,182.15,210.65,260.65
2,360.65,960.65,1110.65,1210.65,1350.65,2*1400.65/
 DATA (D(I,7),I=70,92)/4171.3757,2116.6542,1854.4271,1327.0701,
1639.0688,229.8350,46.6186,11.2008286,1.14403750,.6765775,.34680966
28,.0877758853,4.7124E-3,3.13269E-3,6.28104E-4,1.535937E-4,5.266469
36E-5,1.0572373E-5,7.7162844E-6,5.8329036E-6,3.5198772E-6,2*2.78611
469E-6/
 DATA (D(I,8),I=1,118)     /-5.E3,0.,7979.,8975.,9971.,10966.,11961
1.,12956.,13950.,14944.,15938.,16931.,17925.,18917.,19910.,20902.,
221894.,22886.,23877.,24868.,25858.,26849.,27839.,28829.,29818.,
330807.,31796.,32784.,33773.,34760.,35748.,36735.,37722.,38709.,
439695.,40681.,41667.,42652.,43637.,44622.,45606.,46591.,47574.,
548558.,49541.,50524.,51507.,52489.,53471.,54453.,55434.,56415.,
657396.,58376.,59357.,60336.,61316.,62295.,63274.,64253.,65231.,
766209.,67187.,68164.,69141.,70118.,71095.,72071.,73047.,74022.,
874998.,75973.,76947.,77922.,78896.,79869.,80843.,81816.,82789.,837
962.,84734.,85706.,86677.,87649.,88620.,89590.,90561.,91531.,92501.
A,93470.,94440.,95409.,96377.,97346.,98314.,99281.,100249.,101216.,
B102183.,103149.,104115.,105081.,106047.,107012.,107977.,108942.,10
C9907.,110871.,111835.,112798.,113761.,114724.,115687.,116649.,1176
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D11.,118573.,119535.,1.0E10/
 DATA (D(I,8),I=119,236)    /2*-.003,-8.338E-3,-9.075E-3,-9.608E-3
1,-3.326E-3,-3.622E-3,-3.295E-3,-3.372E-3,-3.681E-3,-3.114E-3,3.28E
2-4,1.992E-3,4.317E-3,4.585E-3,4.618E-3,4.041E-3,3.246E-3,3.431E-3,
31.436E-3,1.26E-3,1.54E-3,1.135E-3,9.08E-4,4.06E-4,1.035E-3,1.639E-
43,1.759E-3,1.335E-3,1.809E-3,3.328E-3,2.917E-3,2.677E-3,2.894E-3,
53.15E-3,2.941E-3,2.951E-3,2.704E-3,2.677E-3,2.909E-3,2.386E-3,4.38
6E-4,-5.83E-4,-6.54E-4,-7.35E-4,-5.68E-4,-1.814E-3,-2.714E-3,-2.795
7E-3,-2.887E-3,-2.016E-4,-1.778E-3,-1.996E-3,-1.758E-3,-1.49E-3,-2.
8513E-3,-3.385E-3,-3.784E-3,-3.759E-3,-3.958E-3,-3.952E-3,-3.946E-3
9,-3.938E-3,-3.928E-3,-3.917E-3,-3.904E-3,-3.889E-3,-4.07E-3,-3.879
AE-3,-4.051E-3,-4.054E-3,-4.243E-3,-4.094E-3,-4.08E-3,-3.17E-4,-3.8
BE-4,-4.55E-4,-5.46E-4,-6.55E-4,-1.131E-3,-4.94E-4,-5.94E-4,-7.14E-
C4,-8.47E-4,1.914E-3,2.41E-3,2.131E-3,2.7E-3,2.87E-3,2.705E-3,3.082
DE-3,2.96E-3,3.211E-3,3.531E-3,5.678E-3,5.913E-3,5.956E-3,6.947E-3,
E6.172E-3,6.697E-3,5.989E-3,6.176E-3,5.824E-3,5.696E-3,1.0344E-2,1.
F0349E-2,1.0355E-2,1.036E-2,1.0364E-2,1.0369E-2,1.0373E-2,1.0377E-2
G,1.0381E-2,1.0405E-2,2.0765E-2,.020776,.00352,.005336895/
 DATA (D(I,8),I=237,354)      /302.15,287.15,249.37,241.06,232.03,22
12.46,219.15,215.55,212.28,208.92,205.27,202.17,202.50,204.48,208.7
26,213.31,217.89,221.9,225.11,228.51,229.94,231.94,232.71,233.83,23
34.73,235.13,236.16,237.78,239.51,240.83,242.62,245.91,248.78,251.4
43,254.28,257.39,260.29,263.19,265.86,268.49,271.36,273.7,274.14,27
53.56,272.96,272.2 ,271.64,269.86,267.19,264.45,261.61,259.64,257.8
69,255.94,254.21,252.75,250.29,246.98,243.27,239.57,235.72,231.85,
7228.,224.15,220.31,216.48,212.67,208.87,204.9,201.12,197.17,193.21
8,189.08,185.09,181.12,180.81,180.44,179.99,179.46,178.83,177.73,17
97.25,176.67,175.98,175.17,177.014,179.35,181.85,184.039,186.845,18
A9.407,192.462,195.314,198.378,201.815,207.304,213.076,218.793,225.
B523,231.48,237.914,243.74,249.713,255.329,260.808,270.845,280.769,
C290.792,300.789,310.79,320.776,330.756,340.731,350.699,360.693,
D380.646,400.598,1400.65/
 DATA (D(I,8),I=355,472)     / 1821.348,1013.25,389.9,339.4,293.9,25
13.,216.8,185.4,158.1,134.6,114.2,96.62,81.67,69.1,58.61,49.88,42.6
21,36.51,31.36,27.,23.29,20.1,17.37,15.02,13.,11.26,9.75,8.452,7.33
35,6.372,5.54,4.824,4.208,3.677,3.217,2.819,2.475,2.176,1.915,1.688
4,1.49,1.317,1.165,1.03,.9107,.805,.7114,.6283,.5545,.4887,.4301,
5.3782,.3322,.2915,.2556,.2239,.196,.1713,.1494,.1301,.113,.09793,
6.08467,.07303,.06283,.05392,.04614,.03938,.03351,.02843,.02404,.02
7026,.01702,.01424,.01187,.00987,.008206,.00682,.005665,.004704,.00
83902,.003235,.00268,.002219,.001836,.00152,.001261,.001048,.000874
9,.0007306,.0006123,.0005146,.0004336,.0003663,.0003103,.0002639,
A.0002254,.0001933,.0001665,.000144,.0001251,.000109,9.534E-5,8.364
BE-5,7.359E-5,6.449E-5,5.765E-5,5.136E-5,4.593E-5,4.124E-5,3.715E-5
C,3.357E-5,3.043E-5,2.767E-5,2.522E-5,2.308E-5,2.121E-5,2.7861169E-
D6/
 DATA (D(I,9),I=1,118)      /-5.E3,0.,7979.,8975.,9971.,10966.,11961
1.,12956.,13950.,14944.,15938.,16931.,17925.,18917.,19910.,20902.,
221894.,22886.,23877.,24868.,25858.,26749.,27839.,28829.,29818.,308
307.,31796.,32784.,33733.,34760.,35748.,36735.,37722.,38709.,39695.
4,40861.,41667.,42652.,43637.,44622.,45606.,46591.,47574.,48558.,49
5541.,50524.,51507.,52489.,53471.,54453.,55434.,56415.,57396.,58376
6.,59357.,60336.,61316.,62295.,63274.,64253.,65231.,66209.,67187.,
768164.,69141.,70118.,71095.,72071.,73047.,74022.,74998.,75973.,769
847.,77942.,78896.,79869.,80843.,81816.,82789.,83762.,84734.,85706.
9,86677.,87649.,88620.,89590.,90561.,91531.,92501.,93470.,94440.,95
A409.,96377.,97346.,98314.,99281.,100249.,101216.,102183,103149.,
B104115.,105081.,106047.,107012.,107977.,108942.,109907.,110871.,11
C1835.,112798.,113761.,114724.,115687.,116649.,117611.,118573.,1195
D35.,1.0E10/
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      DATA (D(I,9),I=119,236)   /2*-.003,-.007918,-.007799,-.007461  ,-.
     1001327,-9.52E-4,-.001113,-8.42E-4,-7.56E-4,-8.85E-4,-.001036,-9.85
     2E-4,-6.96E-4,7.7E-5,4.62E-4,6.31E-4,5.99E-4,.001046,.001596,1.77E-
     33,.001976,.002221,.002781,.003463,.003142,.005101,.005631,.005588,
     4.005807,.003035,.002720,.001692,.001839,.001350,4.72E-4,4.63E-4,7.
     575E-4,1.64E-4,-5.18E-4,.001249,-4.25E-4,-8.73E-4,-6.72E-4,-4.41E-4
     6,1.46E-4,-6.17E-4,-.001655,-.001622,-6.05E-4,-.001071,-6.19E-4,-7.
     762E-4,-9.28E-4,-4.49E-4,-.001409,-.002365,-.002163,-.002263,-.0027
     805,-.002864,-.003034,-.002891,-.002722,-.003160,-.003323,-.003186,
     9-.003629,-.002921,-.004165,-.003532,-.004214,-.004144,-.004296,-6.
     A4E-5,-3.06E-4,-3.34E-4,-6.15E-4,-4.53E-4,-5.11E-4,1.32E-4,-5.38E-4
     B,-6.14E-4,-6.93E-4,.002792,.002947,.002885,.002577,.002446,.002529
     C,.002396,.002005,.002498,.002380,.004293,.0046,.004734,5.16E-3,.00
     D5162,.005164,.005166,.005168,5.17E-3,.005201,.010344,.010349,.0103
     E55,.010360,.010364,.010369,.010373,.010377,.010381,.010405,.020765
     F,.020776,.003352,.005336895/
      DATA (D(I,9),I=237,354)   /302.15,287.15,237.01,229.13,221.36  ,21
     13.94,212.62,211.67,210.56,209.73,208.97,208.1,207.07,206.09,205.4,
     2205.47,205.93,206.56,207.15,208.19,209.77,211.52,213.48,215.68,218
     3.43,221.85,224.96,230.,235.57,241.09,246.82,249.82,252.5,254.17,25
     45.99,257.32,257.78,258.24,259.,259.16,258.65,259.88,259.46,258.61,
     5257.95,257.51,257.65,257.05,255.42,253.83,253.24,252.19,251.58,250
     6.83,249.92,249.48,248.10,245.79,243.67,241.45,238.81,236.,233.04,
     7230.21,227.55,224.47,221.22,218.11,214.57,211.72,207.66,204.21,200
     8.1,196.07,191.88,191.82,191.52,191.2,190.6,190.16,189.66,189.79,18
     99.27,188.67,188.026,190.886,193.557,196.327,198.866,201.267,203.65
     A9,206.053,207.968,210.355,212.677,216.819,221.324,225.851,230.857,
     B234.832,240.778,245.82,250.826,255.815,260.808,270.845,280.769,290
     C.792,300.789,310.79,320.776,330.756,340.731,350.699,360.693,380.64
     D6,400.598,1400.65/
      DATA (D(I,9),I=355,472)   /1821.3378,1013.25,3.484E2,3.0011E2 ,2.5
     188E2,2.213E2,1.887E2,1.607E2,1.368E2,1.163E2,98.86,83.98,71.29,60.
     248,51.27,43.45,36.84,31.25,26.52,22.52,19.14,16.3,13.89,11.86,10.1
     35,8.699,7.475,6.441,5.569,4.832,4.206,3.671,3.209,2.809,2.46,2.157
     4,1.893,1.661,1.458,1.28,1.124,.9869,.8669,.7613,.6683,.5866,.5148,
     5.4518,.3963,.3473,.3042,.2664,.2331,.204,.1784,.156,.1363,.1191,.1
     638,.09044,.07867,.06833,.05925,.05128,.04431,.03822,.0329,.02826,
     7.02422,.02071,.01766,.01502,.01273,.01076,.009062,.007616,.0064,.0
     805377,.004515,.003791,.003181,.002669,.002239,.001878,.001574,.001
     932,.00111,.0009361,.0007912,.0006702,.0005688,.0004837,.0004121,.0
     A003516,.0003006,.0002576,.0002214,.0001909,.0001651,.0001433,.0001
     B247,.0001089,9.529E-5,8.363E-5,7.359E-5,6.499E-5,5.765E-5,5.136E-5
     C,4.593E-5,4.124E-5,3.715E-5,3.357E-5,3.043E-5,2.767E-5,2.522E-5,2.
     D308E-5,2.121E-5,2.7861169E-6/
      N=92
      IF(J.GT.7) N=472
      DO 30 I=1,N
30    DARAY(I)=D(I,J)
      RETURN
      END
```

```
      SUBROUTINE BET(XTCL,TTCL,NXTCL,XV,TX2,NP,XLSTV,IBGN)
      DIMENSION XTCL(1),TTCL(1),TX2(1),XV(1)
      IBGN=1
      DO 100 I=1,NXTCL
      IF(XTCL(I).LT.XLSTV)IBGN=I+1
  100 CONTINUE
      DO 200 I=IBGN,NXTCL
      X=XTCL(I)-XLSTV
  199 CALL DISCT3 (X,XV,TX2,NP,TTCL(I))
C     ***********
  200 CONTINUE
      RETURN
      END
```

```
C     THIS SUBROUTINE DETERMINES THE COEFFICIENTS OF THE MATRIX
      SUBROUTINE COEFF(NPFT,XMSG,RHO7,TABL2,DEN)
C
      DIMENSION CP(50),YK(50),CPGAS(50),HV(50)
      DIMENSION RHO7(50),XMSG(50)
      DIMENSION DEN(50)
C
      COMMON/YYZY/ DSIC(50),RHOCF,SN2,XB2,CA2,HV2
      COMMON /ABPROP/ RHO(50)
      COMMON /BACKUP/ XNPM(12),RHOBX(12),XBM(12),EMBB(12),EMFB(12)
     1      , NKPB(12),NCPB(12),TXK(20,12),XK(20,12),TCP(20,12),NPM(12)
     2      , CPX(20,12),GAPX(12),FTEST(12),BTEST(12),H(12),XKB(10,12)
     3      , CPB(10,12),DXB(12)
      COMMON /TEMPS/ TEMDI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
     1      , TUL2(50),TY(200),TEMPI,TXD,SURTEM
      COMMON /COEFFS/ A(200),B(200),C(200),D(200),AB(10,12),BB(10,12)
     1      , CB(10,12),DB(10,12),SB(10,12),RB1(10,12),RB2(10,12),R(50)
     2      , S(50),INT
      COMMON /ABLATS/ XMDG(50),TABL,TCHAR,RHOV,RHOC,TREC,XLOST,SDOTDS
     1      , SDOT,XMDC,XMT
      COMMON /INDIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      COMMON /TIMES/ TINT,TLIM,T,DT
      COMMON /FNTBCK/ FBLOW,EMV,EMC,H300,TEST2,TENV,DIN,HENV,FENV
     1      , DLOSS,DHC,HXX(12),HX(50),TW(50)
      COMMON /HSPARA/ DX,     TL,VL,BL,DMP,VPT
      COMMON /TRAJ/ TIME(300),DCONC(300),DRAD(300),VEL(300),ALT(300)
     1      , DCON(300),NTRAPT,FCONV,FRAD
      COMMON /ARRH/ THETA(50),AP,XB,SN,CA
      COMMON/TABS/ TNODE(50),DCHAR(50),ITABLE(9,10),ITAB(9,6)
     1            , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2            , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
     3            , ISTART,IEND,ANSWR(350)
      EQUIVALENCE (ANSWR(1),CP(1)),(ANSWR(51),YK(1)),(ANSWR(201),CPGAS(1
     1)),(ANSWR(251),HV(1)),(ANSWR(301),HSUB)
C
      CALL PROP(NTERR)
C     *********
C-----------------------------------------------------------------------
C     WRITE(20,3)
C   3 FORMAT(' PROP CALLED'//)
C-----------------------------------------------------------------------
      IF(NTERR.EQ.1) RETURN
      XFG1=0.
      XFG2=1.
      XIFG3=1.
      XFG7=1.
      IF(TX2(1).LT.TABL)XFG2=0.
      YNP=NP
      S(INT)=(DEN(INT)*DX*CP(INT))/(2.*DT)
      R(INT)=(1.0)/((DX/2.0)*((1.0/YK(INT))+(1.0/YK(INT+1))))
      IF(QCON(1).LT.0.)GO TO 5
      A(INT)=0.0
      B(INT)=-(S(1)+R(1))
      C(INT)=R(1)
      D(INT)=-QIN-S(1)*TX2(1)+(XMDG(1)-XMDG(2))*HV(1)/2.*XFG1+XFG2*CA*
```

```
     10X/2.*HV(1)*(RHO(1)-RHDC)**SN*EXP(-XB/TX2(1))*XIFG3+XMOG(1)*
     2CPGAS(1)/2.*QIN/YK(1)*DX+OEN(1)*CP(1)*SDOT*QIN/2./YK(1)*DX
      IF(TX2(1).LT.TABL2) XFG7=0.
      QSIC(INT)=(XMSG(1)-XMSG(2))*HV2/2.*XFG7
      D(INT)=D(INT)+QSIC(INT)
      XFG7=1.
4     XFG2=1.
      JNT=INT+1
      GO TO 6
5     A(INT)=0.
      B(INT)=0.
      C(INT)=0.
      D(INT)=0.
      S(2)=(DEN(2)*DX*CP(2))/DT
      R(2)=1./((DX/(2.*YK(2)))+(DX/(2.*YK(3))))
      A(2)=0.
      B(2)=-(R(1)+R(2)+S(2)+XMDG(2)*CPGAS(2))
      C(2)=R(2)+XMOG(2)*CPGAS(2)
      IF(TX2(2).LT.TABL)XFG2=0.
      D(2)=-S(2)*TX2(2)-SURTEM*R(1)+XFG2*CA*DX*HV(2)*(RHO(2)-RHOC)**SN
     1*EXP(-XB/TX2(2))*XIFG3
601   XFG2=1.
      JNT=INT+2
6     CONTINUE
      NPP=NP-1
      XFG2=1.
      DO 10 I=JNT,NPP
      XI=I
      S(I)=(OEN(I)*DX*CP(I))/DT
      R(I)=(1.0)/((DX/(2.0*YK(I)))+(DX/(2.0*YK(I+1))))
      A(I)=R(I-1)
      B(I)=-(R(I-1)+R(I)+S(I)+XMDG(I)*CPGAS(I)+DEN(I)*CP(I)
     1        *SDOT*(YNP-XI)/(YNP-1.))
      C(I)=R(I)+XMDG(I)*CPGAS(I)+DEN(I)*CP(I)*SOOT*(YNP-XI)/(YNP-1.)
      IF(TX2(I).LT.TABL)XFG2=0.
      D(I)=-S(I)*TX2(I)+(XMDG(I)-XMDG(I+1))*HV(I)*XFG1+XFG2*XIFG3*CA*
     1HV(I)*(RHO(I)-RHOC)**SN*EXP(-XB/TX2(I))*DX
      IF(TX2(I).LT.TABL2) XFG7=0.
      QSIC(I)=(XMSG(I)-XMSG(I+1))*HV2*XFG7
      D(I)=D(I)+QSIC(I)
      XFG7=1.
9     XFG2=1.
   10 CONTINUE
      R(NP)=(1.0)/((DXB(1)   /(2.0*XKB(1,1)))+(DXB(1)  /(2.0*XKB(2,1))))
      S(NP)=(DEN(NP)*DX*CP(NP)+RHDBX(1)*CPB(1,1)*DXB(1))/(2.*DT)
      A(NP)=R(NP-1)
      B(NP)=(-(                R(NP-1)+R(NP)+S(NP)))
      C(NP)=R(NP)
      IF(TX2(NP).LT.TABL)XFG2=0.
      D(NP)=(-S(NP)*TX2(NP))+XMDG(NP)*HV(NP)*XFG1+XFG2*CA*HV(NP)/2.*
     1(RHO(NP)-RHOC)**SN*EXP(-XB/TX2(NP))*DX*XIFG3
      IF(TX2(NP).LT.TABL2) XFG7=0.
      QSIC(NP)=XMSG(NP)*HV2/2.*XFG7
      D(NP)=D(NP)+QSIC(NP)
19    DO 200 I=1,NMB
      IF(I-1) 20,20,30
   20 AB(1,I)=A(NP)
      BB(1,I)=B(NP)
      CB(1,I)=C(NP)
      DB(1,I)=D(NP)
```

```
      GO TO 65
   30 L=NPM(I-1)
      IF(FTEST(I)) 45,40,45
   40 SB(1,I)=(RHDBX(I)*CPB(1,I)*DXB(I)+RHDBX(I-1)*CPB(L,I-1)*DXB(I-1))/
     1(2.0*DT)
      RB1(1,I)=(1.0)/((DXB(I-1)/(2.0*XKB(L,I-1)))+(DXB(I-1)/(2.0*XKB(L-1
     1,I-1))))
      RB2(1,I)=(1.0)/((DXB(I)/(2.0*XKB(1,I)))+(DXB(I)/(2.0*XKB(2,I))))
      AB(1,I)=RB1(1,I)
      BB(1,I)=(-(RB1(1,I)+RB2(1,I)+SB(1,I)))
      CB(1,I)=RB2(1,I)
      DB(1,I)=(-(SB(1,I)*TX2T(1,I)))
      GO TO 65
   45 IF(FTEST(I)) 50,40,55
   50 G=(1.73E-09)/(1.0/EMBB(I-1)+1.0/EMFB(I)-1.0)
      GO TO 60
   55 G=0.0
   60 SB(1,I)=(RHDBX(I)*CPB(1,I)*DXB(I))/(2.0*DT)
      RB2(1,I)=(1.0)/((DXB(I)/(2.0*XKB(1,I)))+(DXB(I)/(2.0*XKB(2,I))))
      AB(1,I)=H(I-1)+4.0*G*(TX2T(L,I-1)**3)
      BB(1,I)=(-(H(I-1)+4.0*G*(TX2T(1,I   )**3)+RB2(1,I)+SB(1,I)))
      CB(1,I)=RB2(1,I)
      DB(1,I)=3.0*G*((TX2T(L,I-1)**4)-(TX2T(1,I)**4))-SB(1,I)*TX2T(1,I)
   65 LF=NPM(I)-1
      DO 100 J=2,LF
      SB(J,I)=(RHDBX(I)*CPB(J,I)*DXB(I))/DT
      RB1(J,I)=(1.0)/((DXB(I)/(2.0*XKB(J-1,I)))+(DXB(I)/(2.0*XKB(J,I))))
      RB2(J,I)=(1.0)/((DXB(I)/(2.0*XKB(J+1,I)))+(DXB(I)/(2.0*XKB(J,I))))
      AB(J,I)=RB1(J,I)
      BB(J,I)=(-(RB1(J,I)+RB2(J,I)+SB(J,I)))
      CB(J,I)=RB2(J,I)
      DB(J,I)=(-(SB(J,I)*TX2T(J,I)))
  100 CONTINUE
      IF(I-NMB) 110,250,250
  110 LNF=NPM(I)
      IF(BTEST(I)) 120,115,120
  115 SB(LNF,I)=(RHDBX(I)*CPB(LNF,I)*DXB(I)+RHDBX(I+1)*CPB(1,I+1)*DXB(I+
     11))/(2.0*DT)
      RB1(LNF,I)=(1.0)/((DXB(I)/(2.0*XKB(LNF-1,I)))+(DXB(I)/(2.0*XKB(LNF
     1,I))))
      RB2(LNF,I)=(1.0)/((DXB(I+1)/(2.0*XKB(1,I+1)))+(DXB(I+1)/
     1(2.0*XKB(2,I+1))))
      AB(LNF,I)=RB1(LNF,I)
      BB(LNF,I)=(-(RB1(LNF,I)+RB2(LNF,I)+SB(LNF,I)))
      CB(LNF,I)=RB2(LNF,I)
      DB(LNF,I)=(-(SB(LNF,I)*TX2T(LNF,I)))
      GO TO 200
  120 IF(BTEST(I)) 125,115,127
  125 G=(1.73E-09)/(1.0/EMBB(I)+1.0/EMFB(I+1)-1.0)
      GO TO 130
  127 G=0.0
  130 SB(LNF,I)=(RHDBX(I)*CPB(LNF,I)*DXB(I))/(2.0*DT)
      RB1(LNF,I)=(1.0)/((DXB(I)/(2.0*XKB(LNF-1,I)))+(DXB(I)/(2.0*XKB(LNF
     1,I))))
      AB(LNF,I)=RB1(LNF,I)
      BB(LNF,I)=(-(RB1(LNF,I)+H(I)+SB(LNF,I)+4.0*G*(TX2T(LNF,I)**3)))
      CB(LNF,I)=H(I)+4.0*G*(TX2T(1,I+1)**3)
      DB(LNF,I)=3.0*G*((TX2T(1,I+1)**4)-(TX2T(LNF,I)**4))-SB(LNF,I)*TX2T
     1(LNF,I)
  200 CONTINUE
```

```
250 MN=NPM(NMB)
    IF(OLDSS) 270,260,270
260 SB(MN,NMB)=(RHOBX(NMB)*CPB(MN,NMB)*DXB(NMB))/(2.0*DT)
    RB1(MN,NMB)=(1.0)/((DXB(NMB)/(2.*XKB(MN-1,NMB)))+(DXB(NMB)/(2.0*XK
   1B(MN,NMB))))
    AB(MN,NMB)=RB1(MN,NMB)
    BB(MN,NMB)=(-(RB1(MN,NMB)+SB(MN,NMB)))
    CB(MN,NMB)=0.0
    DB(MN,NMB)=(-(SB(MN,NMB)*TX2T(MN,NMB)))
    GO TO 280
270 SB(MN,NMB)=(RHOBX(NMB)*CPB(MN,NMB)*DXB(NMB))/(2.0*DT)
    RB1(MN,NMB)=(1.0)/((DXB(NMB)/(2.0*XKB(MN-1,NMB)))+(DXB(NMB)/(2.0*X
   1KB(MN,NMB))))
    AB(MN,NMB)=RB1(MN,NMB)
    BB(MN,NMB)=(-(RB1(MN,NMB)+HENV+(1.73E-09)*FENV*4.0*(TX2T(MN,NMB)**
   13)+SB(MN,NMB)))
    CB(MN,NMB)=0.0
    DB(MN,NMB)=(-(HENV*TENV+FENV*(1.73E-09)*((TENV**4)+3.0*(TX2T(MN,NM
   1B)**4))+SB(MN,NMB)*TX2T(MN,NMB)))
280 L=NP+1
    DO 300 I=1,NMB
    K=NPM(I)
    IF(I.EQ.1) GO TO 282
    IF(GAPX(I-1).EQ.0.) GO TO 282
    KT=1
    GO TO 285
282 KT=2
285 DO 290 J=KT,K
    A(L)=AB(J,I)
    B(L)=BB(J,I)
    C(L)=CB(J,I)
    D(L)=DB(J,I)
    IF(DMP.GT.0.0) GO TO 289
    IF(DMP) 289,289,286
286 WRITE(20,287) AB(J,I),BB(J,I),CB(J,I),DB(J,I),J,I,A(L),B(L),C(L),
   1D(L),L
287 FORMAT(1H0,8HAB(J,I)=,1PE12.5,2X,8HBB(J,I)=,1PE12.5,2X,8HCB(J,I)=,
   11PE12.5,2X,8HDB(J,I)=,1PE12.5,2X,2HJ=,I3,2X,2HI=,I3/1X,5HA(L)=,1PE
   212.5,2X,5HB(L)=,1PE12.5,2X,5HC(L)=,1PE12.5,2X,5HD(L)=,1PE12.5,2X,2
   3HL=,I3)
289 L=L+1
290 CONTINUE
300 CONTINUE
    NPFT=L-1
    RETURN
    END
```

```
      SUBROUTINE COKE(RHA,TX2,XMOG,OT,OX,NP,SOOT,OMP,XMCOKE,RHOV,SMCOKE)
C
      OIMENSION RHA(50),TX2(200),XMOG(50),XCOKE(50),      XMCOKE(50),
     1RCOKE(50),SMCOKE(50)
C
      XNP=NP
      NPL=NP-1
      MP=NP-1
      OO 100 I=1,NPL
      XI=I
      IF(TX2(I).LT.2500.) GO TO 50
      XCOKE(I)=+0.038*(RHOV-RHA(I) )*3600.*EXP(-6000./TX2(I))
     1 +SOOT*((XNP-XI)/(XNP-1.))*(RHA(I+1)-RHA(I))/OX
      IF(XCOKE(I).LE.0.0) XCOKE(I)=0.0
      IF(I.EQ.1) GO TO 40
      XMCOKE(I)=OX*XCOKE(I)
      GO TO 100
   40 XMCOKE(I)=OX*XCOKE(I)/2.0
      GO TO 100
   50 XCOKE(I)=0.
      XMCOKE(I)=0.
  100 CONTINUE
      XMCOKE(NP)=0.
      XCOKE(NP)=0.
      RCOKE(NP)=0.
      SMCOKE(NP)=0.0
      L=NP-1
      OO 750 I=1,MP
      SMCOKE(L)=SMCOKE(L+1)+XMCOKE(L)
      L=L-1
  750 CONTINUE
      KI=NP-1
      OO 200 J=1,NPL
      IF(SMCOKE(KI).EQ.0.) GO TO 130
      IF(RHA(KI).GE.RHOV ) GO TO 120
      XMOG(KI)=XMOG(KI)-SMCOKE(KI)
      IF(XMOG(KI).LT.0.) XMOG(KI)=0.
      RCOKE(KI)=XCOKE(KI)*OT
      RHA(KI)=RHA(KI)+RCOKE(KI)
      IF(RHA(KI).LE.RHOV ) GO TO 150
  120 RHA(KI)=RHOV
  130 XMCOKE(KI)=0.
      XCOKE(KI)=0.
      RCOKE(KI)=0.
  150 CONTINUE
      IF(OMP) 190,190,170
  170 WRITE(20,180) XMOG(KI),XMCOKE(KI),XCOKE(KI),RCOKE(KI),
     1RHA(KI),TX2(KI),KI
  180 FORMAT(1X,5HXMOG=,1PE12.5,2X,7HXMCOKE=,1PE12.5,2X,6HXCOKE=,1PE12.5
     1,2X,6HRCOKE=,1PE12.5,2X,4HRHA=,1PE12.5,2X,4HTX2=,1PE12.5,2X,3HKI=,
     2I3)
      WRITE(20,300)
  300 FORMAT(//)
  190 KI=KI-1
  200 CONTINUE
      RETURN
      END
```

```
C***
C*** A IS SYMBOL FOR DATA ARRAY IN CALLING PROGRAM
C*** K IS INDEX  FOR DATA ARRAY IN CALLING PROGRAM
C*** X IS FIRST INPUT VARIABLE
C*** Y IS SECOND INPUT VARIABLE
C*** Z IS THE ANSWER (A FUNCTION OF X AND Y)
C***
      SUBROUTINE COMMOL(A,K,X,Y,Z)
      DIMENSION A( 1 ),C(19)
      DATA (C(I),I=1,19)/19*0./
      S313=(X-A(1))/A(2)
      S310=(Y-A(K))/A(K+1)
      M2=A(K+2)
      M4=A(K+3)
      S315=S313**2
      S312=S310**2
      S314=S313*S315
      S311=S310*S312
      N316=8
      IF(M2.EQ.1)GO TO 133
      N316=N316-3
      C(5)=S315
      C(6)=S310*S313
      C(7)=S312
  133 C(8)=S313
      C(9)=S310
      C(10)=1.
      N317=18
      IF(M4-2)203,166,147
  147 N317=N317-4
      C(11)=S314
      C(12)=S310*S315
      C(13)=S312*S313
      C(14)=S311
  166 N317=N317-3
      C(15)=S315
      C(16)=S313*S310
      C(17)=S312
  203 C(18)=S313
      C(19)=S310
      S325=0.
      K=K-1
      M4=N316
      DO 233 J=M4,10
      N321=J+K
      S325=S325+C(J)*A(N321)
  233 CONTINUE
      S324=1.
      M4=N317
      DO 254 J=M4,19
      N321=J+K
      S324=S324+C(J)*A(N321)
  254 CONTINUE
      Z=S325/S324
      RETURN
      END
```

```
      SUBRDUTINE DISCDT (XA,ZA,TABX,TABY,TABZ,NC,NY,NZ,ANS)
      DIMENSIDN TABX(500),TABY(500),TABZ(500),NPX(8),NPY(8),YY(8)
C     DIMENSION TABX(500),TABY(500),TABZ(500),NPX(8),NPY(8),YY(8)
      CALL UNS (NC,IA,IDX,IDZ,IMS)
C     ********
      IF (NZ-1)   5,5,10
    5 CALL DISSER (XA,TABX(1),1,NY,IDX,NN)
C     ***********
      NNN=IDX+1
      CALL LAGRAN (XA,TABX(NN),TABY(NN),NNN,ANS)
C     ***********
      GDTD 70
   10 ZARG=ZA
      IP1X=IDX+1
      IP1Z=IDZ+1
      IF (IA)   15,25,15
   15 IF (ZARG-TABZ(NZ))   25,25,20
   20 ZARG=TABZ(NZ)
   25 CALL DISSER (ZARG,TABZ(1),1,NZ,IDZ,NPZ)
C     ***********
      NX=NY/NZ
      NPZL=NPZ+IDZ
      I=1
      IF (IMS)   30,30,40
   30 CALL DISSER (XA,TABX(1),1,NX,IDX,NPX(1))
C     ***********
      DO 35 JJ=NPZ,NPZL
      NPY(I)=(JJ-1)*NX+NPX(1)
      NPX(I)=NPX(1)
   35 I=I+1
      GDTD 50
   40 DD 45 JJ=NPZ,NPZL
      IS=(JJ-1)*NX+1
      CALL DISSER (XA,TABX(1),IS,NX,IDX,NPX(I))
C     ***********
      NPY(I)=NPX(I)
   45 I=I+1
   50 DO 55 I=1,IP1Z
      NLOC=NPX(I)
      NLDCY=NPY(I)
   55 CALL LAGRAN (XA,TABX(NLDC),TABY(NLOCY),IP1X,YY(I))
C     ***********
      CALL LAGRAN (ZARG,TABZ(NPZ),YY(1),IP1Z,ANS)
C     ***********
   70 RETURN
      END
```

```
      SUBROUTINE DISCT3(XA,TABX,TABY,NY,ANS)
      DIMENSION TABX(1),TABY(1)
      CALL DISSER(XA,TABX,1,NY,2,NN)
C     ***********
      NNN=3
      CALL LAGRAN(XA,TABX(NN),TABY(NN),NNN,ANS)
C     ***********
      RETURN
      END
```

```
      SUBROUTINE DISSER (XA,TAB,I,NX,ID,NPX)
      DIMENSION TAB(2000)
C     DIMENSIDN TAB(2000)
      NPT=ID+1
      NPB=NPT/2
      NPU=NPT-NPB
      IF (NX-NPT)    10,5,10
    5 NPX=I
      RETURN
   10 NLOW=I+NPB
      NUPP=I+NX-(NPU+1)
      DO 15 II=NLDW,NUPP
      NLDC=II
      IF (TAB(II)-XA)    15,20,20
   15 CONTINUE
      NPX=NUPP-NPB+1
      RETURN
   20 NL=NLOC-NPB
      NU=NL+ID
      DO 25 JJ=NL,NU
      NDIS=JJ
      IF (TAB(JJ)-TAB(JJ+1))    25,30,25
   25 CONTINUE
      NPX=NL
      RETURN
   30 IF (TAB(NDIS)-XA)    40,35,35
   35 NPX=NDIS-ID
      RETURN
   40 NPX=NDIS+1
      RETURN
      END
```

```
C
C     SUBROUTINE OOUBLE INTERPOLATES A=F(X,Y)
C
      SUBROUTINE OOUBLE(I,X,Y)
      OIMENSION X(12),Y(12)
      OIMENSION CP(50),YK(50),CPGAS(50),HV(50)
      COMMON/TABS/ TNODE(50),OCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAO,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IEND,ANSWR(350)
      EQUIVALENCE (ANSWR(1),CP(1)),(ANSWR(51),YK(1)),(ANSWR(201),CPGAS(1
     1)),(ANSWR(251),HV(1)),(ANSWR(301),HSUB)
      IS=ITABLE(I,9)+ISTART
      IE=ITABLE(I,9)+IENO
      I1=ISTART-1
      JX=ITABLE(I,2)
      JY=ITABLE(I,3)
      DO 1000 K=IS,IE
      I1=I1+1
      IF(X(I1).GT.TABLES(JX)) GO TO 20
   15 JX=JX-1
      IF(X(I1).GT.TABLES(JX)) GO TO 100
      GO TO 15
   20 IF(X(I1).LT.TABLES(JX+1)) GO TO 100
      JX=JX+1
      GO TO 20
  100 IF(Y(I1).GT.TABLES(JY)) GO TO 120
  115 JY=JY-1
      IF(Y(I1).GT.TABLES(JY)) GO TO 500
      GO TO 115
  120 IF(Y(I1).LT.TABLES(JY+1)) GO TO 500
      JY=JY+1
      GO TO 120
  500 J1=(JY-ITABLE(I,4))*ITABLE(I,7)+JX
      J2=J1+ITABLE(I,7)
      U=(Y(I1)-TABLES(JY))/(TABLES(JY+1)-TABLES(JY))
      T1=TABLES(J1)+(TABLES(J2)-TABLES(J1))*U
      T2=TABLES(J1+1)+(TABLES(J2+1)-TABLES(J1+1))*U
      ANSWR(K)=T1+(T2-T1)*(X(I1)-TABLES(JX))/(TABLES(JX+1)-TABLES(JX))
      IF(K.GT.IS) GO TO 1000
      ITABLE(I,2)=JX
      ITABLE(I,3)=JY
 1000 CONTINUE
      RETURN
      ENO
```

```
      SUBROUTINE OPOX(TY,RHO,RHOV,RHOC,PL,DX,XMOG,N,NP)
      DIMENSION ALPHA(50),BETA(50),XMU(50),RHO(50),TY(50),XMOG(50)
      COMMON /PRES/ P(50),ALFAV,ALFAC,BETAV,BETAC,Z
      DATA TI/1800./,XMUI/2.79E-5/,S/198./
      P(1)=(PL*2116.217)**2
      IF(N.LT.2) GO TO 20
      N1=N-1
      DO 10 I=1,N1
      ALPHA(I)=ALFAV-((ALFAV-ALFAC)/(RHOV-RHOC))*(RHOV-RHO(I))
      BETA(I)=BETAV-((BETAV-BETAC)/(RHOV-RHOC))*(RHOV-RHO(I))
      XMU(I)=XMUI*(TY(I)/TI)**1.5*((TI+S)/(TY(I)+S))
      P(I+1)=P(I)+Z*((ALPHA(I)*XMU(I)+BETA(I)*XMOG(I)/3600.)*
     1XMOG(I)/3600.*TY(I)*DX)
   10 CONTINUE
      GO TO 25
C
   20 N=1
   25 DO 30 I=1,N
   30 P(I)=SQRT(P(I))/144.
      N1=N+1
      DO 50 I=N1,NP
   50 P(I)=P(N)
      RETURN
      END
```

```
C***
C***            FOR REAL GAS  *** USE FINDSR FOR PERFECT GAS SOLUTION
C***
C***
C*** VORT IS V**2/RTO
C*** TOT    IS TO/T
C*** POP  IS P/PO
C*** ROR  IS RHO/RHOO
C*** HORT IS H/RTO
C*** P2P  IS P2/PO
C*** H2RT IS H2/RTO
C*** R2R  IS R2/RO
C*** V    IS V1
C*** SOR  IS S/R
C*** IREG IS AN ERROR FLAG
C***
       SUBROUTINE FINDS(VORT,TOT,POP,ROR,HORT,P2P,H2RT,R2R,V,SOR,IREG)
C
C    SUBROUTINE FOR REAL GAS SOLUTION
C
       S514=.5
       S515=0.
       S525=0.
       N523=0
       S520=(5.*TOT*VORT-1.)/6.
       S521=POP*S520
       S524=S521
       S513=ROR*VORT
       S512=ROR*S513
       S511=.5*VORT+HORT
       S510=POP+S513
       S506=VORT*TOT
       IF(S506-1.4)427,427,146
  146  IF(S506-10.)170,170,153
  153  IF(S521-S513)164,164,160
  160  S521=S513
  164  N522=2
       GO TO 231
  170  IF(S521)427,427,175
  175  N522=1
       GO TO 231
  202  N522=2
       IF(S521)217,212,212
  212  IF(S521-S513)231,231,217
  217  S525=.5*S525
       S521=S524-S525
       GO TO 202
  231  S524=S521
       S507=S510-S521
       R2R=S512/S507
       H2RT=S511-(.5*S507**2/S512)
       S517=ALOG(S521)/2.3025851
       IF(S517+7.)427,427,263
  263  CALL MOLS(S517,H2RT,SOR,IREG)
C      *********
```

```
      IF(IREG-1)433,433,277
  277 CALL MOLR(SOR,H2RT,S527,IREG)
C     *********
      IF(IREG-1)433,433,314
  314 S527=EXP(2.3025851*S527)
      S516=.002498*R2R
      S526=.002498*S527
      S525=S514*(S516-S526)/S516
      S503=R2R/S527
      IF(ABS(1.-S503)-.01)433,433,347
  347 IF(R2R-S527)348,433,357
  348 IF(S515)370,370,362
  357 IF(S515)362,370,370
  362 S525=.5*S525
      S514=.5*S514
  370 S503=1.-.1*S525
      S521=S521*S503
      S515=S525
      IF(S517+6.5)427,407,407
  407 IF(S521)202,202,413
  413 N523=N523+1
      IF(N523-50)414,427,427
  414 IF(N522-1)231,231,202
  427 IREG=1
      GO TO 444
  433 S503=S511-H2RT
      V=SORT(2.*S503)
  444 P2P=S521
      RETURN
      END
```

```
C*****************************************************************
C THIS SUBROUTINE CONTROLS THE INPUT OF NAMELIST VARIABLES AND IT
C ALSO SETS THE NOMINAL VALUE FOR MOST OF THE NAMELIST VARIABLES
C*****************************************************************
C
C
      SUBROUTINE INDATA(JCASE)
      COMMON /BACKUP/ XNPM(12),RHOBX(12),XBM(12),EMBB(12),EMFB(12)
     1     , NKPB(12),NCPB(12),TXK(20,12),XK(20,12),TCP(20,12),NPM(12)
     2     , CPX(20,12),GAPX(12),FTEST(12),BTEST(12),H(12),XKB(10,12)
     3     , CPB(10,12),OXB(12)
      COMMON /TEMPS/ TEMOI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
     1     , TUL2(50),TY(200),TEMPI,TXO,SURTEM
      COMMON /COEFFS/ A(200),B(200),C(200),D(200),AB(10,12),BB(10,12)
     1     , CB(10,12),OB(10,12),SB(10,12),RB1(10,12),RB2(10,12),R(50)
     2     , S(50),INT
      COMMON /ABLATS/ XMOG(50),TABL,TCHAR,RHOV,RHOC,TREC,XLOST,SOOTOS
     1     , SDOT,XMDC,XMT
      COMMON /INOIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      COMMON /TIMES/ TINT,TLIM,T,OT
      COMMON /FNTBCK/ FBLOW,EMV,EMC,H300,TEST2,TENV,QIN,HENV,FENV
     1     , QLOSS,QHC,HXX(12),HX(50),TW(50)
      COMMON /HSPARA/ OX,    TL,VL,BL,OMP,VPT
      COMMON /FIXPRO/ CHARK,CHARC,ABLK,ABLC
      COMMON /TURBU/ WX,RTR,PLPT,SHAPEF
      COMMON /TRAJ/ TIME(300),QCONC(300),QRAO(300),VEL(300),ALT(300)
     1     , QCON(300),NTRAPT,FCONV,FRAO
      COMMON /FIXERS/ I1,I2,I3,I4,I5,I6
      COMMON /JUNK/ ERR1,ERR2,ERR3,ERR4
      COMMON /INPUTS/ NTURBT,MMM,LAST,ITHIN,TFACT,TSUBL,IPRESS,NREAD
     1     , RHOS,XMWG,TABL2,H1(12),HEAO2(12),HEAO3(12),H3(12),OXPLOT
     2     , FBLOWL,FBLOWT,FFLAG,FV,  TTABLE(20),QELTT(20),IPRC(20)
     3     , NPTT,TS(50),SR(50),QCONX,QRAOX,NHP,NPR,NREC,RTEST,SRM1
     4     , SRM2,SRB1,SRB2,KLLL,TV,PLPTX
      COMMON /BULL/ LINE1,LINE2,LINE3
      COMMON /ARRH/ THETA(50),AP,XB,SN,CA
      COMMON /PRES/ P(50),ALFAV,ALFAC,BETAV,BETAC,Z
      COMMON /PLTVAR/ NCPLTC,NCPLOT,NPLOT,NPCAS(25),NPPCAS,TTCL(15)
     1     , TTCLPL(15),XTCLF(15),XTCL(15),NXTCL,XISOTH(4),Y3,Y4,Y5,Y6
     2     , XV(50),XVPNT(50),XVT(50),XLSTI,XMOT
      COMMON/TABS/ TNOOE(50),OCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAO,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IENO,ANSWR(350)
      COMMON/RESCUT/ TCOFF(10),XRECES(10),XVNEW(50)
      COMMON /FACTRS/ AOT(300),FC(300),FR(300),FPLPT(300),SOVR,PHI,
     1                FWX(300),WX1,WX2
      EQUIVALENCE (AINPUT(1),XKREAC),(AINPUT(2),CPREAC),(AINPUT(3),XKCHR
     1),(AINPUT(4),CPCHR),(AINPUT(5),XKVRG),(AINPUT(6),CPVRG),
     2(AINPUT(7),CPGAS),(AINPUT(8),HV),(AINPUT(9),HSUB)
C
      CHARACTER*72 LINE1,LINE2,LINE3
  100 FORMAT(F6.0)
  110 FORMAT(A)
      NAMELIST/INPUT/ ABLC, ABLK, ALFAC, ALFAV, ALT, BETAC, BETAV
```

```
     1               , BTEST, CA, CHARC, CHARK, CPGAS, CPX, DELTT, DHC
     2               , DXPLOT, EMBB, EMC, EMFB, EMV, FBLDWL, FBLOWT
     3               , FCONV, FENV, FFLAG, FRAO, FTEST, FV, GAPX, H
     4               , HENV, HSUB, HSUBV, HV, HX, H300, IPRC, IPRESS
     5               , ITHIN, MMM, NCPB, NCPLDT, NHP, NKPB, NMB
     6               , NP, NPLDT, NPTT, NREAD, NREC, NTRAPT
     7               , NTURBT, NXTCL, PLPTX, QCDNC, QLDSS, QRAO, RHOBX
     8               , RHOC, RHOV, RTR, SHAPEF, SN, SR, TABL, TCHAR, SN2
     9               , TCDFF, TCP, TEMDI, TEMPI, TENV, TEST2, TFACT
     *               , TIME, TINT, TLIM, TREC, TS, TSUBL, TTABLE, TV
     1               , TVAP, TXK, TXO, TW, VEL, VL, VPT, WX, XB, XBM
     2               , XISDTH, XK, XNPM, XRECES, XTCL, Z
     3               , CPCHR , CPREAC, CPVRG, XKCHR , XKREAC, XKVRG,TREAO
     4               , RHOS, TABL2, XMWG
     5               , AOT, SOVR, PHI, WX1, WX2
      ASTRIX = 9999.
      IF(JCASE.GT.0) GO TO 50
      JCASE=1
C
C THE FOLLOWING INITIALIZATIONS ARE THE NOMINAL VALUES AS STATED IN THE
C THE TABLE OF NAMELIST VARIABLES. MOST NOMINAL VALUES HAVE BEEN CHANGED
C TO REFLECT THE VALUES FOR FIREX 273 AND THUS ARE NOT THE SAME VALUES
C AS SPECIFIED IN THE STABII USER'S MANUAL
C
      WX = 1.0
      H300 = 129.06
      NHP  = 42
      RHOV = 32.0
      RHOC = 20.0
      TCHAR= 860.0
      TABL= 660.
      XMWG=15.
      TSUBL=2235.
      TABL2=1.E6
      TFACT=1.
      DHC  = 5000.0
      FBLOWL= 1.00
      FBLOWT= 1.00
      FCONV = 1.0
      FRAD = 1.0
      FV = 1.0
      TV = 535.0
      ABLC = .35
      CHARK = .11
      CHARC = .40
      NCPC = 6
      NREC = 24
      TREC = 2235.0
      NMB = 3
      TENV = 535.0
      TEMPI = 535.0
      HENV = 0.
      FENV = 0.
      QLDSS = 0.
      TEST2  = 0.
      NTURBT = 1
      MMM=6
      RTR = 80000.
      SHAPEF = .05532
      TINT = 0.
```

```
      NPLOT=0
      NCPLOT=0
      NCPLTC =1
C
      NREAD = 0
      DXPLOT =100.
      ALFAV = 7.153E10
      ALFAC = 5.781E9
      BETAV = 0.
      BETAC = 1.924E5
      Z = 3.15
      IPRESS = 0
      SN=1.0
      CA=9.5E7
      XB=.233E5
      EMV=.99
      EMC=.65
      RHDS=16.
      ABLK=.072
      ITHIN=1
C NOMINAL VALUE OF PLPTX CHANGED TO 1.
      PLPTX=1.
C
   50 READ(5,100) H1(1)
      IF(H1(1).EQ.ASTRIX) LAST=1
      IF(LAST.EQ.1) RETURN
      READ(5,110) LINE1
      READ(5,110) LINE2
      READ(5,110) LINE3
      READ (5,INPUT)
C NREAD SHOULD ALWAYS EQUAL 0
      IF(NREAD.EQ.0) GO TO 80
      I=0
  60  I=I+1
      READ(5,70) TIME(I),QCONC(I),QRAD(I),VEL(I),ALT(I),AOT(I)
      AOT(I)=180.-ADT(I)
      IF(ALT(I).GT.0.) GO TO 60
      TIME(I)=TIME(I-1)+50.
      ALT(I)=10000.
      TIME(I+1)=TIME(I)+100.
      ALT(I+1)=6780.
      TIME(I+2)=TIME(I+1)+100.
      ALT(I+2)=3560.
      TIME(I+3)=TIME(I+2)+110.
      ALT(I+3)=10.
      NTRAPT=I+3
      DO 65 K=I,NTRAPT
      QCONC(K)=0.
      QRAD(K)=0.
      ADT(K)=0.
  65  VEL(K)=20.
      TINT=TIME(1)
      TLIM=TIME(NTRAPT)
  70  FORMAT(6E12.5)
  80  CONTINUE
      NPBS=0
      BL=0.
      DO 90 I=1,NMB
      BL=BL+XBM(I)
      NPM(I)=XNPM(I)+.0000002
   90 NPBS = NPBS + XNPM(I)+ .5
C
      RETURN
      END
```

```
      SUBROUTINE INWRIT(IRANGE)
      DIMENSION HEAD(12),HEADG(12)
      DIMENSION QCONW(300),QRADW(300)
C
      COMMON /BACKUP/ XNPM(12),RHOBX(12),XBM(12),EMBB(12),EMFB(12)
     1     , NKPB(12),NCPB(12),TXK(20,12),XK(20,12),TCP(20,12),NPM(12)
     2     , CPX(20,12),GAPX(12),FTEST(12),BTEST(12),H(12),XKB(10,12)
     3     , CPB(10,12),QXB(12)
      COMMON /TEMPS/ TEMOI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
     1     , TUL2(50),TY(200),TEMPI,TXO,SURTEM
      COMMON /COEFFS/ A(200),B(200),C(200),D(200),AB(10,12),BB(10,12)
     1     , CB(10,12),DB(10,12),SB(10,12),RB1(10,12),RB2(10,12),R(50)
     2     , S(50),INT
      COMMON /ABLATS/ XMDG(50),TABL,TCHAR,RHOV,RHOC,TREC,XLOST,SOOTOS
     1     , SDOT,XMOC,XMT
      COMMON /INDIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      COMMON /TIMES/ TINT,TLIM,T,DT
      COMMON /FNTBCK/ FBLOW,EMV,EMC,H300,TEST2,TENV,QIN,HENV,FENV
     1     , QLOSS,QHC,HXX(12),HX(50),TW(50)
      COMMON /HSPARA/ QX,    TL,VL,BL,DMP,VPT
      COMMON /FIXPRO/ CHARK,CHARC,ABLK,ABLC
      COMMON /TURBU/ WX,RTR,PLPT,SHAPEF
      COMMON /TRAJ/ TIME(300),QCONC(300),QRAD(300),VEL(300),ALT(300)
     1     , QCON(300),NTRAPT,FCONV,FRAD
      COMMON /FIXERS/ I1,I2,I3,I4,I5,I6
      COMMON /JUNK/ ERR1,ERR2,ERR3,ERR4
      COMMON /INPUTS/ NTURBT,MMM,LAST,ITHIN,TFACT,TSUBL,IPRESS,NREAD
     1     , RHOS,XMWG,TABL2,H1(12),HEAD2(12),HEAD3(12),H3(12),QXPLOT
     2     , FBLOWL,FBLOWT,FFLAG,FV,  TTABLE(20),QELTT(20),IPRC(20)
     3     , NPTT,TS(50),SR(50),QCONX,QRADX,NHP,NPR,NREC,RTEST,SRM1
     4     , SRM2,SRB1,SRB2,KLLL,TV,PLPTX
      COMMON /BULL/ LINE1,LINE2,LINE3
      COMMON /ARRH/ THETA(50),AP,XB,SN,CA
      COMMON /PRES/ P(50),ALFAV,ALFAC,BETAV,BETAC,Z
      COMMON /PLTVAR/ NCPLTC,NCPLOT,NPLOT,NPCAS(25),NPPCAS,TTCL(15)
     1     , TTCLPL(15),XTCLF(15),XTCL(15),NXTCL,XISOTH(4),Y3,Y4,Y5,Y6
     2     , XV(50),XVPNT(50),XVT(50),XLSTI,XMOT
      COMMON/TABS/ TNODE(50),QCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IENO,ANSWR(350)
      COMMON /TURBWT/ RENOLA(300),QTOLA(300)
      COMMON /FACTRS/ AQT(300),FC(300),FR(300),FPLPT(300),SOVR,PHI,
     1                FWX(300),WX1,WX2
      COMMON /QREF/ QCONT(300),QRADT(300),QTOTAL(300),QTCL,QTRL,QTCRL,
     1             QCMAX,QCMAXT,QRMAX,QRMAXT,QCANR,QCANRT
      EQUIVALENCE (H1,HEAD), (H3,HEADG)
      EQUIVALENCE (AINPUT(1),XKREAC),(AINPUT(2),CPREAC),(AINPUT(3),XKCHR
     1),(AINPUT(4),CPCHR),(AINPUT(5),XKVRG),(AINPUT(6),CPVRG),
     2(AINPUT(7),CPGAS),(AINPUT(8),HV),(AINPUT(9),HSUB)
      CHARACTER*72 LINE1,LINE2,LINE3
C
   10 FORMAT(1H1,37X33HSTAB II CHARRING ABLATION PROGRAM///,
     13(A,/)//,30H INPUT AND INITIALIZATION DATA//)
   11 FORMAT(5X66HCONSTANT FACTORS WILL BE USED. ANGLE-OF-ATTACK HISTORY
```

```
     1 IS IGNOREO./5X6HFCONV=1PE11.5,5X5HFRAO=1PE11.5,5X3HWX=1PE11.5,
     25H (FT),5X6HPLPTX=1PE11.5//)
   12 FORMAT(14H INITIAL TIME=1PE10.4, 6H (SEC),6X11HTIME LIMIT=1PE10.4,
     16H (SEC)// ,8X4HTIME,10X9HTIME STEP,6X13HPRINT CONTROL/,
     38X5H(SEC),11X5H(SEC),6X17H(TIME STEP/PRINT)/,
     4(5X1PE10.4,6X1PE10.4,9XI4))
   13 FORMAT(17H LOCATION SUMMARY)
   14 FORMAT(5X5HSOVR=1PE11.5,5X4HPHI=1PE11.5,6H (OEG)//)
   15 FORMAT(5X5HSOVR=1PE11.5,5X4HPHI=1PE11.5,6H (OEG),5X4HWX1=1PE11.5,
     15H (FT),5X4HWX2=1PE11.5,5H (FT)//)
   16 FORMAT(//30H ARRHENIUS EQUATION PARAMETERS/,
     15X,2HN=E16.7,5X,2HA=E16.7,5X,2HB=E16.7)
   22 FORMAT(//3X5HTABL=1PE11.5,8H (OEG-R),3X5HABLC=1PE11.5,11H (BTU/LB-
     1R),6X5HRHOV=1PE11.5,9H (LB/FT3),6X3HNP=I2/,2X6HTCHAR=1PE11.5,
     28H (DEG-R),3X5HABLK=1PE11.5,14H (BTU/HR-FT-R),3X5HRHOC=1PE11.5,
     39H (LB/FT3),5X4HMMM=I2/,3X5HTREC=1PE11.5,8H (OEG-R),2X6HCHARC=,
     41PE11.5,11H (BTU/LB-R),6X5HRHOS=1PE11.5,9H (LB/FT3),2X7HNTURBT=I2/
     55X3HTV=1PE11.5,8H (OEG-R),2X6HCHARK=1PE11.5,14H (BTU/HR-FT-R),
     65X3HFV=1PE11.5,12X6HITHIN=I2/,5X3HVL=1PE11.5,5H (IN),8X3HHV=,
     71PE11.5,11H (BTU/LB-R),7X4HOHC=1PE11.5,9H (BTU/LB),5X4HEMV=1PE11.5
     8/,8H FBLOWL=1PE11.5,10X6HCPGAS=1PE11.5,11H (BTU/LB-R),6X5HHSUB=,
     91PE11.5,9H (BTU/LB),5X4HEMC=1PE11.5/,8H FBLOWT=1PE11.5,12X4HRTR=,
     *1PE11.5,17X5HH300=1PE11.5,9H (BTU/LB),9H  SHAPEF=1PE11.5)
24    FORMAT(48X,1PE12.5,3X,1PE12.5)
26    FORMAT(2X,1PE12.5,4X,1PE12.5)
28    FORMAT(//33X,14HCHAR  MATERIAL/20X,7HTHERMAL,38X,8HSPECIFIC/3X,11H
     1TEMPERATURE,4X,12HCONDUCTIVITY,19X,11HTEMPERATURE,7X,4HHEAT,/,
     2(2X,1PE12.5,4X,1PE12.5,18X,1PE12.5,3X,1PE12.5))
   30 FORMAT(1H1,24H SURFACE RECESSION TABLE//,12H TEMPERATURE,5X17HSURF
     1ACE RECESSION/3X7H(OEG-R),12X8H(IN/SEC)/,(1PE12.5,7X1PE12.5))
   32 FORMAT(//29H THERMOCOUPLE LOCATIONS  (IN)/,(1P5E20.8))
   46 FORMAT(21H1REFERENCE TRAJECTORY,6X64H***NOTE  IF QCONC(1).LT.0.0,
     1THEN THE Q RAOIATIVE ARRAY CONTAINS/,36X67HSURFACE TEMPERATURE (OE
     2G-F) ANO THE Q CONVECTIVE ARRAY IS NOT USEO.//4X26HNO. OF TRAJECTO
     3RY POINTS =,I4///,8X4HTIME,8X12HQ CONVECTIVE,4X11HQ RAOIATIVE,
     48X8HVELOCITY,8X8HALTITUOE,5X15HANGLE OF ATTACK/,8X5H(SEC),
     57X13H(BTU/FT2-SEC),3X13H(BTU/FT2-SEC),6X8H(FT/SEC),10X4H(FT),
     612X5H(OEG)//,(1P6E16.5))
   47 FORMAT(1X106H***THE ANGLE OF ATTACK TABLE WAS EXCEEOED. ENO-POINT
     1VALUES WERE USEO IN THE VARIABLE FACTORS CALCULATION.)
   48 FORMAT(///35H PROPERTIES OF THE BACKUP STRUCTURE/,
     1/4X,35HNO. OF MATERIALS IN BACK-UP SHIELO=I4,/,4X,
     240HTOTAL NUMBER OF NOOES IN BACK-UP SHIELD=I4,/,4X,
     328HTHICKNESS OF BACK-UP SHIELD=1PE12.5///4X19HTEMPERATURE (OEG-R),
     45X34HTHERMAL CONOUCTIVITY (BTU/HR-FT-R),5X24HSPECIFIC HEAT (BTU/LB
     5-R)/)
   50 FORMAT(20X7HTHERMAL,38X8HSPECIFIC/,3X11HTEMPERATURE,4X,     12HCONO
     1UCTIVITY,19X,11HTEMPERATURE,7X,4HHEAT,/,
     2(2X,1PE12.5,4X,1PE12.5,18X,1PE12.5,3X,1PE12.5))
52    FORMAT(///55X,10HEMISSIVITY/8X,8HMATERIAL,5X,7HOENSITY,7X,9HTHICKN
     1ESS,7X5HFRONT,9X4HBACK,7X14HNOOES/MATERIAL,/21X8H(LB/FT3),
     210X4H(IN)/,(11XI2,8X1PE10.4,4X1PE10.4,4X1PE10.4,4X1PE10.4,
     35X1PE10.4))
54    FORMAT(//4X,60HAOOITIONAL OATA FOR INDIVIDUAL MATERIALS IN BACKUP
     1STRUCTURE//11X,8HMATERIAL,5X,16HFILM COEFFICIENT,5X,13HGAP THICKNE
     2SS,8X5HFTEST,13X5HBTEST/,25X14H(BTU/HR-FT2-R),10X4H(IN)/,
     3(13XI3,12X1PE10.4,9X1PE10.4,7X1PE11.4,7X1PE11.4))
   56 FORMAT(/4X18HCABIN TEMPERATURE=1PE12.5,8H (OEG-R),5X19HHEAT LOSS T
     1O CABIN=1PE12.5,17H (BTU/HR-FT2-SEC)//,4X21HVIEW FACTOR TO CABIN=,
     21PE12.5,10X26HFILM COEFFICIENT TO CABIN=1PE12.5,15H (BTU/HR-FT2-R)
```

```
     3//)
  58 FORMAT(64H TEMPERATURE OISTRIBUTION IN TEST SPECIMEN IS ARBRITARY
     1 (OEG-R)/,(1P8E12.5))
  60 FORMAT(67H TEMPERATURE DISTRIBUTION IN TEST SPECIMEN IS UNIFORM AN
     1O EQUAL TO ,1PE10.4,8H (OEG-R))
  62 FORMAT(66H LINEAR TEMPERATURE OISTRIBUTION ASSUMEO IN TEST SPECIME
     1N (OEG-R)/,(1PE12.5))
  70 FORMAT(52H1TRAJECTORY WITH LOCAL HEATING RATES  (LAMINAR CASE)//,
     14X26HNO. OF TRAJECTORY POINTS =,I4//56X5HLOCAL,11X5HLOCAL/,
     28X4HTIME,11X8HVELOCITY,8X8HALTITUOE,4X12HQ CONVECTIVE,4X11HQ RAOIA
     3TIVE/,8X5H(SEC),10X8H(FT/SEC),10X4H(FT),7X13H(BTU/FT2-SEC),
     443X13H(BTU/FT2-SEC)//,(1P5E16.5))
  75 FORMAT(54H1TRAJECTORY WITH LOCAL HEATING RATES  (TURBULENT CASE)//
     14X26HNO. OF TRAJECTORY POINTS =,I4//51X5HLOCAL,10X5HLOCAL,10X,
     25HLOCAL,9X9HTURBULENT/,6X4HTIME,10X8HVELOCITY,7X8HALTITUOE,
     35X12HQ CONVECTIVE,3X11HQ RAOIATIVE,4X12HREYNOLOS NO.,6X6HFACTOR/,
     46X5H(SEC),9X8H(FT/SEC),9X4H(FT),7X13H(BTU/FT2-SEC),2X,
     513H(BTU/FT2-SEC)//,(1P7E15.7))
  80 FORMAT(//39X10HINTEGRATEO,15X10HINTEGRATEO,15X10HINTEGRATEO/,
     117X4HTIME,17X12HQ CONVECTIVE,13X11HQ RAOIATIVE,13X15HQ CON. + Q RA
     20./,(1P4E25.7))
      WRITE(20,10) LINE1, LINE2, LINE3
      WRITE(20,13)
      IF(PLPTX.LE.0.) GO TO 95
      WRITE(20,11) FCONV,FRAO,WX,PLPTX
      GO TO 102
  95  IF(SOVR.GT.1.) GO TO 100
      WRITE(20,14) SOVR,PHI
      GO TO 102
 100  WRITE(20,15) SOVR,PHI,WX1,WX2
 102  CONTINUE
      WRITE(20,12) TINT, TLIM, (TTABLE(I),OELTT(I),IPRC(I),I=1,NPTT)
      WRITE(20,16) SN,CA,XB
 104  VLP=VL*12.
      WRITE(20,22) TABL,ABLC,RHOV,NP,TCHAR,ABLK,RHOC,MMM,TREC,CHARC,
     1             RHOS,NTURBT,TV,CHARK,FV,ITHIN,VLP,HV,OHC,EMV,FBLOWL,
     2             CPGAS,HSUB,EMC,FBLOWT,RTR,H300,SHAPEF
 120  WRITE(20,30) (TS(I),SR(I),I=1,NREC)
      WRITE(20,32) (XTCL(I),I=1,NXTCL)
      WRITE(20,46) NTRAPT,(TIME(I),QCONC(I),QRAO(I),VEL(I),ALT(I),AOT(I)
     1            ,I=1,NTRAPT)
      IF(IRANGE.EQ.1) WRITE(20,47)
 136  BLP=BL*12.
      WRITE(20,48) NMB,NPBS,BLP
      OO 150 I=1,NMB
      LK=NKPB(I)
      LCP=NCPB(I)
      KLLL=MINO(LK,LCP)
      WRITE(20,50) (TXK(N,I),XK(N,I),TCP(N,I),CPX(N,I),N=1,KLLL)
      IF(LK-LCP) 140,150,144
 140  KLLLL=KLLL+1
      WRITE(20,24) (TCP(N,I),CPX(N,I),N=KLLLL,LCP)
      GO TO 150
 144  KLLLL=KLLL+1
      WRITE(20,26) (TXK(N,I),XK(N,I),N=KLLLL,LK)
 150  CONTINUE
      WRITE(20,52) (LLJ,RHOBX(LLJ),XBM(LLJ),EMFB(LLJ),
     1              EMBB(LLJ),XNPM(LLJ),LLJ=1,NMB)
      WRITE(20,54) (J,H(J),GAPX(J),FTEST(J),BTEST(J),J=1,NMB)
      WRITE(20,56) TENV,HENV,FENV,QLOSS
```

```
      IF(TEST2) 156,158,160
  156 WRITE(20,58) (TEMDI(K),K=1,NPF)
      GO TO 162
  158 WRITE(20,60) TEMPI
      GO TO 162
  160 WRITE(20,62) (TEMDI(L),L=1,NPF)
  162 CONTINUE
      IF(QCONC(1).LT.0.) GO TO 500
      DO 200 I=1,NTRAPT
      QCONW(I)=FC(I)*QCON(I)
      QRADW(I)=FR(I)*QRAD(I)
  200 CONTINUE
      IF(NTURBT.NE.0) GO TO 300
      WRITE(20,70) NTRAPT,(TIME(I),VEL(I),ALT(I),QCONW(I),QRADW(I),I=1,
     1NTRAPT)
      GO TO 400
  300 WRITE(20,75) NTRAPT,(TIME(I),VEL(I),ALT(I),QCONW(I),QRADW(I),
     1             RENOLA(I),QTOLA(I),I=1,NTRAPT)
C               Q-REFERENCE
  400 QCMAX=0.0
      QCMAXT=0.0
      QRMAX=0.0
      QRMAXT=0.0
      QCANR=0.0
      QCANRT=0.0
      QTCL=0.
      QTRL=0.
      QTCRL=0.
      QCONT(1)=0.
      QCONT(NTRAPT)=0.
      QRADT(1)=0.
      QRADT(NTRAPT)=0.
      QTOTAL(1)=0.
      QTOTAL(NTRAPT)=0.
      DO 450 I=2,NTRAPT
      IF(QCONC(I).LT.QCMAX) GO TO 410
      QCMAX=QCONC(I)
      QCMAXT=TIME(I)
  410 IF(QRAD(I).LT.QRMAX) GO TO 420
      QRMAX=QRAD(I)
      QRMAXT=TIME(I)
  420 IF(QCONC(I)+QRAD(I).LT.QCANR) GO TO 430
      QCANR=QCONC(I)+QRAD(I)
      QCANRT=TIME(I)
  430 J=I-1
      DTD=TIME(I)-TIME(J)
      QTCL=QTCL+DTD*(QCONC(I)+QCONC(J))/2.
      QTRL=QTRL+DTD*(QRAD(I)+QRAD(J))/2.
      QCONT(I)=QCONT(J)+DTD*(QCONW(I)+QCONW(J))/2.
      QRADT(I)=QRADT(J)+DTD*(QRADW(I)+QRADW(J))/2.
      QTOTAL(I)=QCONT(I)+QRADT(I)
  450 CONTINUE
      QTCRL=QTCL+QTRL
      WRITE(20,80) (TIME(I),QCONT(I),QRADT(I),QTOTAL(I),I=1,NTRAPT)
  500 RETURN
      END
```

```
      SUBROUTINE ISOTHM(DEPTH,TEMP,BOND,N,ANS,ITT1,ITT2)
      DIMENSION DEPTH(1),TEMP(1)
      ANS=0.
      K=N-1
      DO 100 I=1,K
      IF(TEMP(I)-BOND)2,1,3
    1 ANS=DEPTH(I)
      GO TO 100
    2 IF(TEMP(I+1)-BOND)100,100,4
    4 ANS=DEPTH(I+1)-(TEMP(I+1)-BOND)*(DEPTH(I+1)-DEPTH(I))/(TEMP(I+1)-
     1TEMP(I))
      GO TO 100
    3 IF(TEMP(I+1)-BOND)5,100,100
    5 ANS=(TEMP(I)-BOND)*(DEPTH(I+1)-DEPTH(I))/(TEMP(I)-TEMP(I+1))+DEPTH
     1(I)
  100 CONTINUE
      IF(BOND.EQ.TEMP(N))ANS=DEPTH(N)
      RETURN
      END
```

```
      SUBROUTINE LAGRAN (XA,X,Y,N,ANS)
      DIMENSION X(200),Y(200)
C     DIMENSION X(200),Y(200)
      SUM=0.0
      DO 3 I=1,N
      PROD=Y(I)
      DO 2 J=1,N
      A=X(I)-X(J)
      IF (A)   1,2,1
    1 B=(XA-X(J))/A
      PROD=PROD*B
    2 CONTINUE
    3 SUM=SUM+PROD
      ANS=SUM
      RETURN
      END
```

```
C  THIS PROGRAM WAS WRITTEN BY DR DONALD M. CURRY OF THE NASA MANNED
C  SPACECRAFT CENTER IN HOUSTON, TX.  LT RICHARD A. SCHWARTING, USN
C  BROUGHT THE PROGRAM TO DRAPER LABS AND USED THE PRDGRAM IN HIS
C  THESIS WORK (SEE MIT OCEAN ENGINEERING THESIS BY LT SCHWARTING,
C  MAY 1983). THE THESIS WAS SUPERVISED BY RICHARD T. MARTORANA
C  DF GROUP 2DF AND THE DOCUMENTATION FOR THE PROGRAM I.E. USER'S
C  MANUAL CAN BE FOUND IN GROUP 2DF.
C-----------------------------------------------------------------
C     THIS PRDGRAM DETERMINES THE PERFDRMANCE DF A CHARRING ABLATDR
C-----------------------------------------------------------------
C
      DIMENSIDN CP(50),YK(50),CPGAS(50),HV(50)
      DIMENSIDN DL1(50),DL2(50),RL1(50),TIN(10),TOUT(10),TUL2R(500),
     1TXAR(500)
      DIMENSION TUL3R(600),THETA2(50),XMSG(50),RHD7(50),RHOR2(600)
      DIMENSION XMCDKE(50),RHA(50),SMCDKE(50),DEN(50)
C
      CDMMON/YYZY/ QSIC(50), RHOCF, SN2, XB2, CA2, HV2
      COMMDN /ABPRDP/ RHD(50)
      CDMMDN /BACKUP/ XNPM(12),RHOBX(12),XBM(12),EMBB(12),EMFB(12)
     1     , NKPB(12),NCPB(12),TXK(20,12),XK(20,12),TCP(20,12),NPM(12)
     2     , CPX(20,12),GAPX(12),FTEST(12),BTEST(12),H(12),XKB(10,12)
     3     , CPB(10,12),DXB(12)
      COMMON /TEMPS/ TEMOI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
     1     , TUL2(50),TY(200),TEMPI,TXO,SURTEM
      COMMON /COEFFS/ A(200),B(200),C(200),D(200),AB(10,12),BB(10,12)
     1     , CB(10,12),DB(10,12),SB(10,12),RB1(10,12),RB2(10,12),R(50)
     2     , S(50),INT
      COMMON /ABLATS/ XMOG(50),TABL,TCHAR,RHDV,RHOC,TREC,XLOST,SDDTDS
     1     , SOOT,XMOC,XMT
      COMMON /INDIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      CDMMDN /TIMES/ TINT,TLIM,T,DT
      COMMON /FNTBCK/ FBLOW,EMV,EMC,H300,TEST2,TENV,QIN,HENV,FENV
     1     , QLOSS,DHC,HXX(12),HX(50),TW(50)
      CDMMON /HSPARA/ DX,    TL,VL,BL,OMP,VPT
      COMMON /FIXPRO/ CHARK,CHARC,ABLK,ABLC
      COMMON /TURBU/ WX,RTR,PLPT,SHAPEF
      COMMON /TRAJ/ TIME(300),QCONC(300),QRAD(300),VEL(300),ALT(300)
     1     , QCON(300),NTRAPT,FCONV,FRAD
      CDMMDN /FIXERS/ I1,I2,I3,I4,I5,I6
      CDMMDN /JUNK/ ERR1,ERR2,ERR3,ERR4
      COMMDN /INPUTS/ NTURBT,MMM,LAST,ITHIN,TFACT,TSUBL,IPRESS,NREAD
     1     , RHDS,XMWG,TABL2,H1(12),HEAD2(12),HEAD3(12),H3(12),DXPLOT
     2     , FBLDWL,FBLDWT,FFLAG,FV,TTABLE(20),DELTT(20),IPRC(20)
     3     , NPTT,TS(50),SR(50),QCONX,QRADX,NHP,NPR,NREC,RTEST,SRM1
     4     , SRM2,SRB1,SRB2,KLLL,TV,PLPTX
      COMMON /BULL/ LINE1,LINE2,LINE3
      CDMMDN /ARRH/ THETA(50),AP,XB,SN,CA
      CDMMON /PRES/ P(50),ALFAV,ALFAC,BETAV,BETAC,Z
      CDMMON /PLTVAR/ NCPLTC,NCPLDT,NPLOT,NPCAS(25),NPPCAS,TTCL(15)
     1     , TTCLPL(15),XTCLF(15),XTCL(15),NXTCL,XISOTH(4),Y3,Y4,Y5,Y6
     2     , XV(50),XVPNT(50),XVT(50),XLSTI,XMDT
      COMMON/TABS/ TNODE(50),DCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
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```
     3           , ISTART,IENO,ANSWR(350)
      COMMON/RESCUT/ TCOFF(10),XRECES(10),XVNEW(50)
      COMMON /TRBATS/ PLA(300),TLA(300),HLA(300),VLA(300),TTA(300)
      COMMON /FACTRS/ AOT(300),FC(300),FR(300),FPLPT(300),SDVR,PHI,
     1                FWX(300),WX1,WX2
      COMMON /QREF/ QCONT(300),QRADT(300),QTOTAL(300),QTCL,QTRL,QTCRL,
     1              QCMAX,QCMAXT,QRMAX,QRMAXT,QCANR,QCANRT
      EQUIVALENCE (H1,HEAD), (H3,HEADG)
      EQUIVALENCE (ANSWR(1),CP(1)),(ANSWR(51),YK(1)),(ANSWR(201),CPGAS(1
     1)),(ANSWR(251),HV(1)),(ANSWR(301),HSUB)
      CHARACTER*72 LINE1,LINE2,LINE3
C
   10 FORMAT(1H1,6X44HVL WAS NOT INPUT. THIS CASE WILL BE SKIPPED.)
   15 FORMAT(////,5X,43HPROGRAM DOES NOT PERMIT INITIALIZATION WHEN
     122H THERE IS INITIAL CHAR)
   20 FORMAT (1H1,12HOUTPUT DATA.//)
   25 FORMAT(1HO,80H THE RANGE OF THE ENTHALPY-TEMPERATURE CURVE FIT WAS
     1EXCEEDED AT A TEMPERATURE OF,1E10.4)
   35 FORMAT(/1X,25HTHE VALUES OF TXAR(J) ARE/1X,6(1PE12.5))
   40 FORMAT(//13H ****** TIME=,1PE12.5,9X10HTIME STEP=1PE12.5//,
     115X6HFCONV=1PE12.5,16X5HFRAD=1PE12.5,16X9HVELOCITY=1PE12.5/,
     28X13HQ CONVECTIVE=1PE12.5,9X12HQ RADIATIVE=1PE12.5,9X16HANGLE OF A
     3TTACK=1PE12.5/,3X18HGAS ABLATION RATE=1PE12.5,2X19HCHAR ABLATION R
     4ATE=1PE12.5,5X20HTOTAL ABLATION RATE=1PE12.5/,5X16HRECESSION DEPTH
     5=1PE12.5,6X15HRECESSION RATE=1PE12.5,8X17HSUBLIMATION RATE=,
     61PE12.5)
   45 FORMAT(/10X,4HQIN=1PE12.5,7X7HQRERAD=1PE12.5,7X7HTQSUBL=1PE12.5,
     18X6HALPHA=1PE12.5/,4X10HQHDT WALL=1PE12.5,8X6HQSIO2=1PE12.5,
     27X7HTQOXID=1PE12.5,9X5HBCOF=1PE12.5/,10X4HQWB=1PE12.5,9X5HTQIN=,
     31PE12.5,6X8HTQRERAD=1PE12.5,12X2HG=1PE12.5/,7X7HQBLOCK=1PE12.5,
     49X5HTQHW=1PE12.5,7X7HHTX-HW=1PE12.5,11X3HPL=1PE12.5/,8X6HQSUBL=,
     51PE12.5,7X7HTQRADX=1PE12.5,10X4HHTX=1PE12.5,9X5HPLPT=1PE12.5/,
     68X6HQDXID=1PE12.5,6X8HTQBLOCK=1PE12.5,8X6HRHDST=1PE12.5,11X3HWX=,
     71PE12.5)
   50 FORMAT(/5X,41HSURFACE RECESSION IS DIFFUSION CONTROLLED/)
   55 FORMAT(/5X,45HSURFACE RECESSION IS REACTION RATE CONTROLLED/)
   60 FORMAT(//60H   TEST SPECIMEN PROFILES AT THE END OF THE TIME STEP,
     1 TIME=,1PE12.5)
   65 FORMAT(/6X1HX,7X11HTEMPERATURE,4X7HDENSITY,5X5HTHETA,7X5HM DOT,
     19X6HM COKE,9X7HMT COKE,6X8HPRESSURE/5X4H(IN),7X7H(DEG-F),
     26X8H(LB/FT3),9X,3(4X11H(LB/FT2-HR)),5X5H(PSI)/,
     3(F10.5,F12.1,F13.2,F11.4,3E15.7,F11.4))
   70 FORMAT(//61H   TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE
     1(DEG-F)/,(6E16.7))
   75 FORMAT(//3X24HPENETRATION DEPTHS  (IN)//,6X12HMAX DEPTH OF,F8.2,
     118H (DEG-F) ISOTHERM=E12.5/,6X12HMAX DEPTH OF,F8.2,18H (DEG-F) ISO
     2THERM=E12.5//,6X,8HDEPTH OF,F8.2,18H (DEG-F) ISOTHERM=E12.5,
     36X8HDEPTH OF,F7.5,15H DENSITY RATIO=E12.5/,6X8HDEPTH OF,F8.2,
     418H (DEG-F) ISOTHERM=E12.5,6X8HDEPTH OF,F7.5,15H DENSITY RATIO=,
     5E12.5)
   80 FORMAT(//3X30HEQUIVALENT TEST SPECIMEN LOSS=F10.5,5H (IN),6X32HEQU
     1IVALENT TEST SPECIMEN LENGTH=F10.5,5H (IN))
   85 FORMAT(1H1,47X8HCASE NO.,I3)
   90 FORMAT(1H1,3(A,/))
   95 FORMAT(/7X40H*****TEMPERATURES ARE IN DEGREES F.*****,//
     17X4HVL =F6.3,2X4HNP =I3,2X18HINITIAL VELOCITY =F7.0,2X34HINITIAL T
     2EMPERATURE = DISTRIBUTION,/7X16HEXECUTION TIME =,F5.2,
     35H SEC.,5X20HNO. OF PLOT POINTS =I4//)
  100 FORMAT(/,7X40H*****TEMPERATURES ARE IN DEGREES F.*****,//
     17X4HVL =F6.3,2X4HNP =I3,2X18HINITIAL VELOCITY =F7.0,2X21HINITIAL T
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     2EMPERATURE =F6.2/7X16HEXECUTION TIME =,F5.2,5H SEC.,5X,
     32OHNO. OF PLOT POINTS =I4//)
  105 FORMAT(7X,28HTOTAL CONVECTIVE HEAT LOAO =,F9.1,4H BTU,49H   TOTAL
     1REFERENCE LAMINAR CONVECTIVE HEAT LOAO =,F9.1,/,7X28HTOTAL RAOIANT
     2 HEAT LOAO    =,F9.1,4H BTU,49H   TOTAL REFERENCE LAMINAR RAOIANT
     3HEAT LOAO    =,F9.1,/7X28HTOTAL CONV + RAO HEAT LOAO =,F9.1,4H BTU
     4,49H   TOTAL REFERENCE LAMINAR CONV + RAO HEAT LOAO =,F9.1,//)
  110 FORMAT(7X,4OHMAXIMUM REFERENCE CONVECTIVE HEAT RATE =,F8.2,
     136H   TIME OF MAX REF. CONV HEAT RATE =,F8.1,/7X, 4OHMAXIMUM REFER
     2ENCE RAOIANT HEAT RATE    =,F8.2,36H   TIME OF MAX REF. RAO. HEAT
     3RATE =,F8.1,/7X4OHMAXIMUM REFERENCE CONV + RAO HEAT RATE =,F8.2,
     436H   TIME OF MAX REF TOTAL HEAT RATE =,F8.1//)
  115 FORMAT(7X,3OHMAXIMUM CONVECTIVE HEAT RATE =,F8.2,4OH      TIME OF
     1MAX CONVECTIVE HEAT RATE =,F8.1,/7X3OHMAXIMUM RAOIANT HEAT RATE
     2 =,F8.2,4OH      TIME OF MAX RAOIANT HEAT RATE    =,F8.1,/7X3OHMAX
     3IMUM CONV + RAO HEAT RATE =,F8.1,4OH      TIME OF MAX CONV + RAO H
     4EAT RATE =,F8.1,//)
  120 FORMAT(7X18HTOTAL Q-HOT WALL =F9.2,8X15HTOTAL Q-RAO.  =F9.2,
     18X16HTOTAL Q-RERAO. =F9.2/,7X18HTOTAL Q-BLOCK    =F9.2,8X,
     215HTOTAL Q-SUBL. =F9.2,8X16HTOTAL Q-IN     =F9.2/,7X,
     318HTOTAL Q-COMB.    =F9.2//)
  125 FORMAT(7X16HMAXIMUM DEPTH OF,F7.1,11H ISOTHERM =,F8.3,11H  TIME WH
     1EN,F7.1,3OH ISOTHERM REACHEO MAX OEPTH  =,F8.1,/7X16HMAXIMUM OEPTH
     1 OF,F7.1,11H ISOTHERM =,F8.3,11H  TIME WHEN,F7.1,
     13OH ISOTHERM REACHEO MAX OEPTH  =,F8.1/,7X34HMAXIMUM SURFACE TEMPE
     2RATURE      =F8.1,48H  TIME WHEN MAX SURFACE TEMPERATURE OCCURREO
     3  =F8.1/,7X34HMAXIMUM BONOLINE TEMPERATURE     =F8.1,48H  TIME WHE
     4N MAX BONOLINE TEMPERATURE OCCURREO  =F8.1/,            7X34HBONOL
     5INE TEMPERATURE AT IMPACT   =,F8.1,48H                  TIME TO I
     6MPACT              =,F8.1,//)
  130 FORMAT(7X26HTOTAL SURFACE RECESSION  =,F7.3,3H IN,/1H1)
  135 FORMAT(1H1,//,(5X13HPLOT CASE NO.,I4,5H  HAS,I5,2X7HPOINTS.))
C
      NCASE=0
      LAST=0
C     REWIND 16
      JCASE=0
      LFLG=1
      CALL TBLST(1)
C     **********
  200 CONTINUE
      CALL RESET
C     **********
      IF(LFLG.EQ.1) OELTT(1)=0.
      LFLG=0
      DO 205 I=1,10
  205 TCOFF(I)=2.E6
      CALL INDATA(JCASE)
C     **********
      IF( LAST.EQ.1) GO TO 725
C
C     INITIALIZATION
C
C UNIT 10 USED FOR PLOTING AND IS UNNECESSARY
C     IF(NCASE.EQ.0.AND.NCPLOT.GT.0) REWIND 10
C     IF(NPLOT.GT.0) WRITE(10) (H1(I),I=1,12), (HEAD2(I),I=1,12),
C    1               (HEAD3(I),I=1,12), NXTCL, TINT, QCONC(1)
      NPPCAS=0
      ICT=0
      ICOUNT=0
```

```
JEND=0
IFTC=1
IPLOT=1
ICUT=1
INT=1
NK=1
IEM=1
IBC=1
I17=1
NRS=2
I1=2
I2=2
I3=2
I4=2
I5=2
I6=2
ADTX=0.
OMP=0.
SXO=0.0
SDOT=0.0
SOOTS=0.0
XLSTV=0.0
XLOST=0.0
XLOSTS=0.
XMT=0.0
XMDT=0.0
XMDS=0.0
XMOC=0.0
XMAXI=0.
XMAX2=0.
OCONM=0.0
ORAOM=0.0
OTM=0.0
TCONM=0.
TRAOM=0.
TQTM=0.
TFNM=0.0
TLNM=0.0
OHW1=0.
ODXIO1=0.
OBLOC1=0.
ORERA1=0.
OSUBL1=0.
ORAOX1=0.
TQHW=0.
TOOXIO=0.
TOBLOC=0.
TORERA=0.
TOSUBL=0.
TORADX=0.
TOIN=0.
ERR2=0.
ERR5=0.0
SN2=1.0
XB2=63500.
CA2=7.9E09
RHOCF=12.8
HV2=3220.
HSID2=29000.
BETAT=.20
```

```
      BETAL=.25
      XMP=22.
      XMC=28.
      NTR=NTRAPT-1
      T=TINT
      IF(T.LT.TIME(1)) T=TIME(1)
      IF(TLIM.GT.TIME(NTRAPT)) TLIM=TIME(NTRAPT)
      DO 210 I=1,NXTCL
  210 XTCLF(I)=XTCL(I)/12.
      DO 215  I=1,NTRAPT
  215 QCON(I)=QCONC(I)
      IF(QCONC(1).LT.0.) NTURBT=0
      DO 225 I=1,10
      TOUT(I)=2.E6
  225 TIN(I)=2.E6
      IF(VL.GT.0 .) GO TO 230
      WRITE(20,10)
      GO TO 200
  230 NPX=VL/.07+1.
      IF(NP.LE.0) NP=NPX
      NNPM=NP-1
      XNP=NP
      NP2=NP/2
      IFPT=1
      IF(NP2*2.EQ.NP)IFPT=0
      NPF=NP+NPBS
      VL=VL/12.0
      VLV=VL
      BL=BL/12.0
      TL=VL+BL
      DX=VL/(XNP-1.0)
      IF(TEST2) 235,255,255
  235 DO 240 K=1,NP
      TX1(K)=TEMDI(K)
      TX2(K)=TX1(K)
      TUL1(K)=TX1(K)
      TUL2(K)=TX1(K)
  240 CONTINUE
      L=NP+1
      DO 250 I=1,NMB
      LN=NPM(I)
      DO 245 J=1,LN
      TX2T(J,I)=TEMDI(L)
      L=L+1
  245 CONTINUE
  250 CONTINUE
      TEMPW=-1.0E7
      GO TO 260
  255 TEMPW=TEMPI-460.
      IF(TEST2.GT.0.) TEMPW=-1.0E7
      CALL TEMPO
C     **********
  260 AP=CA*(RHOV-RHOC)**(SN-1.)
      AP2=CA2*(RHOC-RHOCF)**(SN2-1.)
      DO 265 I=1,NP
      XMOG(I)=0.
      THETA(I)=1.0
      IF(SN.EQ.1.) THEN
      TUL2(I)=0.
      ELSE
```

```
      TUL2(I)=1./(1.-SN)
      ENO IF
      RHO(I)=RHOV
      RHO7(I)=RHOC
      XMSG(I)=O.
      RHA(I)=RHOC
      OEN(I)=RHOV
      IF(TX2(I).GT.TABL) GO TO 270
  265 CONTINUE
      GO TO 275
  270 WRITE(20,15)
      GO TO 200
  275 XMMM=MMM
      NPSO=MMM*(NP-1)+1
      DO 280 I=1,NPSO
C THIS LOGIC IMPLIES THAT SN=SN2
      IF(SN.EQ.1.) THEN
      TUL2R(I)=O.
      ELSE
      TUL2R(I)=1./(1.-SN)
      ENO IF
      IF(SN2.EQ.1.) THEN
      TUL3R(I)=O.
      ELSE
      TUL3R(I)=1./(1.-SN2)
      ENO IF
      RHOR2(I)=RHOC
      IF(TUL2R(I).GT.TABL) GO TO 270
  280 CONTINUE
      XV(1)=O.O
      OO 285 I=2,NP
      XV(I)=XV(I-1)+OX
  285 CONTINUE
C THE NEXT IF IS CUT SINCE PLPTX WILL ALWAYS >O
C     IF(PLPTX.LE.O.) GO TO 287
      OO 286 I=1,NTRAPT
      FC(I)=FCONV
      FR(I)=FRAO
      FWX(I)=WX
      FPLPT(I)=PLPTX
  286 CONTINUE
      GO TO 288
C
C THIS SUBROUTINE SHOULO NOT BE CALLEO---SINCE PLPTX SHOULD
C ALWAYS BE >O/
C 287 CALL FACTR(NTRAPT,OCONC(1),IERR,IRANGE)
C     **********
C
C     IF(IERR.GT.O) GO TO 200
  288 CALL TURF(OCON,VEL,ALT,NTRAPT,OCONC,RTR,OMP,SHAPEF,ITHIN,TIN,TOUT,
     1          NTURBT,TIME)
C     *********
      IF(OELTT(1).GT.O.) GO TO 295
      LFLG=1
      NPTT=1
      TTABLE(1)= TIME(1)
      DELTT(1)=.1
      IPRC(1)=500.*TFACT+.5
      OO 290 I = 2,NTRAPT
      IF (OCON(I) .LT. 1.E-03) OTT =10.
```

```
      IF (QCON(I) .GT.0.0 .AND. QCON(I).LT.  10.) DTT =1.
      IF (QCDN(I) .GT. 10.0 .AND. QCON(I) .LT. 20.) DTT = .5
      IF (QCON(I) .GT. 20.0 .AND. QCON(I) .LT. 30.) DTT = .25
      IF(QCDN (I).GT. 30.0.AND. QCON (I).LT. 200.)DTT =.1
      IF( QCON (I) .GT.200.0 .AND. QCON(I)  .LT. 700.) DTT = .05
      IF( QCON (I) .GT. 700.0 .AND. QCON(I) .LT. 1100.) DTT =.025
      IF( QCON (I) . GT. 1100.) DTT = .01
      ILAST = I
      IF (QCON(I).GT. QCON(I-1))ILAST =I-1
      IF (QCON(I) .GT. QCDN(I-1) .AND. DTT .GT. DELTT(NPTT)) GO TO 290
      IF(ABS((DTT -DELTT(NPTT))/DELTT(NPTT)).LT.0.01)  GO TO 290
      IF( NPTT .GE. 20) GO TO 290
      NPTT = NPTT + 1
      TTABLE(NPTT) = TIME(ILAST)
      DELTT(NPTT) = DTT
      IPRC(NPTT)=50.*TFACT/DTT+0.5
  290 CONTINUE
  295 DTS=DELTT(1)
      DT= DELTT(1)/3600.0
      CALL INWRIT(IRANGE)
C     ***********
      CALL TBLST(2)
C     **********
      IF(IERROR.EQ.1) GO TO 200
      WRITE(20,20)
C
C     TIME STEP
C
  300 IF(T.LT.TIME(IFTC+1)) GO TO 310
      IFTC=IFTC+1
      IF(IFTC+1.GT.NTRAPT) GO TO 305
      GO TO 300
  305 T=TIME(NTRAPT)
  310 TFTC=(T-TIME(IFTC))/(TIME(IFTC+1)-TIME(IFTC))
      TX=TLA(IFTC)+(TLA(IFTC+1)-TLA(IFTC))*TFTC
      TT=TTA(IFTC)+(TTA(IFTC+1)-TTA(IFTC))*TFTC
      HL=HLA(IFTC)+(HLA(IFTC+1)-HLA(IFTC))*TFTC
      VX=VLA(IFTC)+(VLA(IFTC+1)-VLA(IFTC))*TFTC
      PL=PLA(IFTC)+(PLA(IFTC+1)-PLA(IFTC))*TFTC
      VELX= VEL(IFTC)+ (VEL(IFTC+1)-VEL(IFTC))*TFTC
      ALTX= ALT(IFTC)+ (ALT(IFTC+1)-ALT(IFTC))*TFTC
      IF(PLPTX.LE.0.) GO TO 313
      PLPT=PLPTX
      IF(QCONC(1).GE.0.) GO TO 317
      GO TO 314
  313 PLPT=FPLPT(IFTC)+(FPLPT(IFTC+1)-FPLPT(IFTC))*TFTC
      IF(QCONC(1).GE.0.) GO TO 315
  314 SURTEM=QRAO(IFTC)+(QRAO(IFTC+1)-QRAO(IFTC))*TFTC+460.
      GO TO 425
  315 FCONV=FC(IFTC)+(FC(IFTC+1)-FC(IFTC))*TFTC
      FRAD =FR(IFTC)+(FR(IFTC+1)-FR(IFTC))*TFTC
  317 QCONX=FCDNV*(QCDN(IFTC)+(QCON(IFTC+1)-QCDN(IFTC))*TFTC)
      QRAOX=FRAD* (QRAO(IFTC)+(QRAO(IFTC+1)-QRAD(IFTC))*TFTC)
C               MAX HEATING RATES AND TIME
      IF(QCONX.LT.QCONM) GO TO 320
      QCONM=QCDNX
      TCONM=T
  320 IF(QRADX.LT.QRADM) GO TO 325
      QRAOM=QRAOX
      TRAOM=T
```

```
  325 IF((QCONX+QRADX).LT.QTM) GO TO 330
      QTM=QCONX+QRADX
      TOTM=T
C-----------------------------------------------------------------
C     WRITE(20,328)
C 328 FORMAT(' TIME STEP CALC'//)
C-----------------------------------------------------------------
C
C               WALL ENTHALPY VS. WALL TEMPERATURE
C
  330 IF(TX2(1).GE.TW(I17).AND.TW(1).LT.TW(I17+1)) GO TO 345
      IF(TX2(1).GE.TW(I17+1)) GO TO 335
      I17=I17-1
      IF(I17.GE.1) GO TO 330
      GO TO 340
  335 I17=I17+1
      IF(I17+1.LE.NHP) GO TO 330
  340 T=TLIM
      WRITE(20,25) TX2(1)
      GO TO 645
  345 HW=HX(I17)+(HX(I17+1)-HX(I17))/(TW(I17+1)-TW(I17))
     1   *(TX2(1)-TW(I17))
C-----------------------------------------------------------------
C     WRITE(20,350)
C 350 FORMAT(' WALL ENTHALPY CALC'//)
C-----------------------------------------------------------------
C               TOTAL ENTHALPY
      HTX=H300+VELX**2/50056.5
C-----------------------------------------------------------------
C     WRITE(20,355)
C 355 FORMAT(' TOTAL ENTHALPY CALC'//)
C-----------------------------------------------------------------
C
C     COMPUTE HEAT IN OUE TO SURFACE COMBUSTION
C
      XMOO=XMDC
      CALL OXIOAT(XMOO,OOXIO)
C     ***********
C
C     COMPUTE Q-HOT WALL
C
      Z1=(HTX-HW)/(HTX-H300)
      IF(Z1.LT.0.) Z1=0.
      IF(Z1.GT.1.) Z1=1.
      QHW=Z1*QCONX
      QBLOCK=0.
      QWB=QHW
      YMT=(XMOG(1)+XMDC)/3600.
      XM2=XMP/(1.-((XMOC/3600.)*YMT)*(1.-XMP/XMC))
      BETA=BETAL
      FBLOW=FBLOWL
  385 IF(T.LT.TIN(IBC)) GO TO 395
      IF(T.LE.TOUT(IBC)) GO TO 390
      IBC=IBC+1
      GO TO 385
  390 FBLOW=FBLOWT
      BETA=BETAT
  395 ALPHA=FBLOW*(28.97/XM2)**BETA
      IF(QHW.EQ.0.) BCOF=0.
      XAB=ALPHA*BCOF
```

```
      GO TO 397
  396 BCOF=YMT*(HTX-HW)/QHW
      XAB=ALPHA*BCOF
  397 IF(XAB.LE.0.) GO TO 400
      IF(XAB.GT.40.) XAB=40.
      G=XAB/(EXP(XAB)-1.)
      IF(G.GT.1.) G=1.
      QWB=G*QHW
      QBLOCK=QHW-QWB
C-----------------------------------------------------------------
C     WRITE(20,403)
C 403 FORMAT(' Q-HOT WALL CALC'//)
C-----------------------------------------------------------------
  400 CONTINUE
C
C     NET HEAT INTO FRONT SURFACE
C
      IF(TX2(1).GT.TCHAR) IEM=2
      IF(IEM.EQ.2) GO TO 405
      EMX=EMV
      GO TO 410
  405 EMX=EMC
  410 QRERAO=(4.8333E-13)*FV*EMX*(TX2(INT)**4-TV**4)
      QSUBL=SOOTS*HSUB*RHOS/3600.
      QSIO2=XMSG(1)*HSIO2/3600.
      QIN=QRAOX+QHW+QOXIO-QBLOCK-QRERAO-QSUBL+QSIO2
      TQHW=TQHW+((QHW1+QHW)/2.)*DTS
      QHW1=QHW
      TQOXIO=TQOXIO+((QOXIO1+QOXIO)/2.)*DTS
      QOXIO1=QOXIO
      TQBLOC=TQBLOC+((QBLOC1+QBLOCK)/2.)*DTS
      QBLOC1=QBLOCK
      TQRERA=TQRERA+((QRERA1+QRERAO)/2.)*DTS
      QRERA1=QRERAO
      TQSUBL=TQSUBL+((QSUBL1+QSUBL)/2.)*DTS
      QSUBL1=QSUBL
      TQRAOX=TQRAOX+((QRAOX1+QRAOX)/2.)*DTS
      QRAOX1=QRAOX
      TQIN=TQRAOX+TQHW+TQOXID-TQBLOC-TQRERA-TQSUBL
      QIN=QIN*3600.
C-----------------------------------------------------------------
C     WRITE(20,413)
C 413 FORMAT(' HEAT - FRONT SURFACE'//)
C-----------------------------------------------------------------
C
C     CHECK FOR FRONT SURFACE RECESSION (CHAR LAYER REMOVAL)
C
      DELH=HTX-HW
      DELSS=XMSG(1)-XMSG(2)
      RHOST=RHOS+DEN(1)-RHOC
      CALL RECESS(XMOC,XLOST,TREC,DT,RHOC,TS,SR,TX2(1),NREC,NRS,ERR5,SXO
     1,SOOT,OMP,SPRINT,RHOST,QWB,DELH)
C     ***********
      CALL SUBL(TX2(1),PLPT,SOOTS,TS,SR,ALTX,NREC,SOOT,VELX,PL1,PL,PT2,
     1TSUBX,TSUBL)
C     **********
C-----------------------------------------------------------------
C     WRITE(20,414)
C 414 FORMAT(' RECESS CALLED, SUBL CALLED'//)
C-----------------------------------------------------------------
```

```
      IF(TX2(1).LT.TSUBL) GO TO 415
      XMOS=SOOTS
      SOOTS=SOOTS/RHOST
      GO TO 420
  415 XMOS=0.0
      SOOTS=0.0
  420 XLOSTS=SOOTS*OT
      IF(ERR5) 465,465,695
  425 IF(ICUT.GT.10) GO TO 465
      XLOST=0.
      IF(T+OTS.LT.TCOFF(ICUT)) GO TO 465
      VLV=VLV-XRECES(ICUT)/12.
      OXV=VLV/(XNP-1.)
      XVNEW(1)=0.
      DO 430 I=2,NP
  430 XVNEW(I)=XVNEW(I- 1)+DXV
      OL1(1)=SURTEM
      OO 450 J=1,NNPM
      XTEST=XVNEW(J)+XRECES(ICUT)/12.
      OO 435 I=1,NNPM
      IF(XV(I).LE. XTEST  .AND. XTEST  .LT.XV(I+1)) GO TO 440
  435 CONTINUE
  440 IF(J.EQ.1) GO TO 445
      OL1(J)=TX2(I)+(TX2(I+1)-TX2(I))/(XV(I+1)-XV(I))*( XTEST  -XV(I))
  445 OL2(J)=TUL2(I)+(TUL2(I+1)-TUL2(I))/OX *(XTEST-XV(I))
  450 RL1(J)=RHO(I)+(RHO(I+1)-RHO(I))/(XV(I+1)-XV(I))*(XTEST-XV(I))
      OO 455 I=1,NNPM
      RHO(I)=RL1(I)
      THETA(I)=(RHO(I)-RHOC)/(RHOV-RHOC)
      TUL2(I)=OL2(I)
  455 TX2(I)=DL1(I)
      OO 460 I=1,NP
  460 XV(I)=XVNEW(I)
      XLOST=XRECES(ICUT)/12.
      ICUT=ICUT+1
      GO TO 475
  465 VLV=VLV-XLOST-XLOSTS
      SOOTT=SOOT+SOOTS
      OXV=VLV/(XNP-1.0)
      XV(1)=0.0
      OO 470 I=2,NP
      XV(I)=XV(I-1)+OXV
  470 CONTINUE
  475 XLSTV=XLSTV+XLOST+XLOSTS
      XLSTI=XLSTV*12.
      OXOLO =OX
      DX=OXV
      OO 485 I=1,50
      IF(THETA(I).LE..01) GO TO 480
      DEN(I)=RHO(I)
      GO TO 485
  480 OEN(I)=RHA(I)
  485 CONTINUE
      CALL COEFF(NPFT,SMCOKE,RHO7,2500.,OEN)
C     **********
C-----------------------------------------------------------------
C     WRITE(20,487)
C 487 FORMAT(' COEFF CALLED'//)
C-----------------------------------------------------------------
      IF(IERROR.EQ.1) GO TO 200
```

```
      IF(ERR2.NE.0.) GO TO 695
      IF(QCON(1).GE.0.) GO TO 495
      NPFTT=NPFT-1
      DO 490 I=1,NPFTT
      J=I+1
      A(I)=A(J)
      B(I)=B(J)
      C(I)=C(J)
  490 D(I)=D(J)
      GO TO 500
  495 NPFTT=NPFT
  500 CALL SWUFT(A,B,C,D,TY,NPFTT,DMP)
C     **********
C-----------------------------------------------------------------
C     WRITE(20,510)
C 510 FORMAT(' SWUFT CALLED'//)
C-----------------------------------------------------------------
      IF(QCDN(1).GE.0.) GO TO 520
      DO 515 I=1,NPFTT
      J=NPFTT+2-I
  515 TY(J)=TY(J-1)
      TY(1)=SURTEM
  520 DO 525 I=1,NP
      TX1(I)=TX2(I)
      TX2(I)=TY(I)
  525 CONTINUE
      IF(TX2(1).LT.TFNM) GO TO 527
      TFNM=TX2(1)
      TIFNM=T+DTS
  527 IF(TX2(NP).LT.TLNM) GO TO 528
      TLNM=TX2(NP)
      TILNM=T+DTS
  528 IF(MMM.GT.1) GO TO 530
      CALL ABLATE(XV,JEND)
C     ***********
C-----------------------------------------------------------------
C     WRITE(20,529)
C 529 FORMAT(' ABLATE CALLED'//)
C-----------------------------------------------------------------
      GO TO 560
  530 LYZ=1
      DXM=DXV/XMMM
      DO 540 I=1,NNPM
      X=0.
      DO 535 J=1,MMM
      TXAR(LYZ)=TX2(I)+(TX2(I+1)-TX2(I))/DXV*X
      X=X+DXM
  535 LYZ=LYZ+1
  540 CONTINUE
      TXAR(LYZ)=TX2(NP)
      IF(DMP) 550,550,545
  545 WRITE(20,35) (TXAR(J),J=1,NPSD)
  550 CALL ABL2(TUL2R,TXAR,NPSD,NP,RHOC,RHOV,SN,SDOT,DT,DXM,AP,XB,CA,
     1XMDG,THETA,RHO,MMM,DMP,TABL,TABL2,JEND,IENTER)
C     *********
C-----------------------------------------------------------------
C     WRITE(20,553)
C 553 FORMAT(' ABL2 CALLED'//)
C-----------------------------------------------------------------
      IF(IENTER.LE.0) GO TO 560
```

```
      CALL ABL2(TUL3R,TXAR,NPSO,NP,RHOCF,RHOC,SN2,SOOT,OT,OXM,AP2,XB2,
     1CA2,XMSG,THETA2,RHO7,MMM,OMP,TABL2,OUMYT,NOTHNG,IENTER)
C     *********
C-----------------------------------------------------------------
C     WRITE(20,557)
C 557 FORMAT(' ABL2 CALLED AGAIN'//)
C-----------------------------------------------------------------
  560 CALL COKE(RHA,TX2,XMOG,OT,OX,NP,SOOT,OMP,XMCOKE,RHOV,SMCOKE)
C     *********
C-------------------------------------------------------------
C     WRITE(20,562)
C 562 FORMAT(' COKE CALLED'//)
C-------------------------------------------------------------
      XMOT=XMOG(1)+XMOC
      IF(VELX.LE.2000..AND.VELX.GT.1100.) PL=PLPT
      IF(VELX.LE.1100.) PL=1.
      IF(IPRESS.NE.1) GO TO 565
      CALL OPOX(TX2,RHO,RHOV,RHOC,PL,OX,XMOG,JENO,NP)
C     *********
C-----------------------------------------------------------------
C     WRITE(20,563)
C 563 FORMAT(' OPOX CALLED'//)
C-----------------------------------------------------------------
      GO TO 575
  565 DO 570 I=1,NP
  570 P(I)=PL*14.6959
  575 LT=NP+1
      DO 590 I=1,NMB
      LLT=NPM(I)
      IF(I.EQ.1) GO TO 580
      IF(GAPX(I-1).EQ.0.) GO TO 580
      KKT=1
      GO TO 585
  580 KKT=2
  585 DO 590 J=KKT,LLT
      TX2T(J,I)=TY(LT)
      LT=LT+1
  590 CONTINUE
      DO 605 I=1,NMB
      IF(I.EQ.1) GO TO 595
      IF(GAPX(I-1).EQ.0.) GO TO 600
      GO TO 605
  595 TX2T(1,1)=TY(NP)
      GO TO 605
  600 LX=NPM(I-1)
      TX2T(1,I)=TX2T(LX,I-1)
  605 CONTINUE
      CALL ISOTHM(XV,TX2,XISOTH(1),NP,Y3,I1060,L1060)
C     ***********
C-----------------------------------------------------------------
C     WRITE(20,607)
C 607 FORMAT(' ISOTHM CALLED'//)
C-----------------------------------------------------------------
      CALL ISOTHM(XV,TX2,XISOTH(2),NP,Y4,I1460,L1460)
C     ***********
C-----------------------------------------------------------------
C     WRITE(20,608)
C 608 FORMAT(' ISOTHM CALLED AGAIN'//)
C-----------------------------------------------------------------
      Y3=Y3*12.+XLSTI
```

```
      Y4=Y4*12.+XLSTI
      IF(Y4.LT.XMAX2) GO TO 610
      XMAX2=Y4
      TXMAX2=T
  610 IF(Y3.LT.XMAXI) GO TO 615
      XMAXI=Y3
      TXMAX=T
C NOTE NPLOT WILL ALWAYS <=0, WHICH DIRECTS YOU TO LINE 620
  615 IF(NPLOT.LE.0) GO TO 620
      IF(T.LT.TIME(IPLOT)) GO TO 620
      IPLOT=IPLOT+1
      CALL ISOTHM(XV,THETA,XISOTH(3),NP,Y5,IP1,LP1)
C     **********
C-----------------------------------------------------------------
C     WRITE(20,617)
C 617 FORMAT(' ISOTHM CALLED'//)
C-----------------------------------------------------------------
      CALL ISOTHM(XV,THETA,XISOTH(4),NP,Y6,IP9,LP9)
C     **********
C-----------------------------------------------------------------
C     WRITE(20,618)
C 618 FORMAT(' ISOTHM CALLED AGAIN'//)
C-----------------------------------------------------------------
      Y5=Y5*12.+XLSTI
      Y6=Y6*12.+XLSTI
      CALL BET(XTCLF,TTCL,NXTCL,XV,TX2,NP,XLSTV,IBGN)
C     ********
C-----------------------------------------------------------------
C     WRITE(20,619)
C 619 FORMAT(' BET CALLED'//)
C-----------------------------------------------------------------
C
C DO NOT CALL THIS SUBROUTINE (TPLOT)
C
C     CALL TPLOT(T,XLSTI,TX2,Y3,Y4,Y5,Y6,SOOTT,OCONX,ORAOX,OHW,OWB,
C    1           XMDT,TTCL,NP,NPPCAS)
  620 CONTINUE
      LM=NP+1
      DO 625 I=1,NMB
      LZ=NPM(I)
      DO 625 J=1,LZ
      TX2(LM)=TX2T(J,I)
      LM=LM+1
  625 CONTINUE
      DO 635 I=2,NPTT
      IF(T-TTABLE(I)) 630,630,635
  630 OTS=OELTT(I-1)
      IPRCT=IPRC(I-1)
      OT=OELTT(I-1)/3600.0
      GO TO 640
  635 CONTINUE
      OTS=OELTT(NPTT)
      IPRCT=IPRC(NPTT)
      OT=OELTT(NPTT)/3600.0
  640 ICT=ICT+1
C
C     PRINT OUT
C
  645 IF(T.EQ.0.) GO TO 650
      IF((T+OTS-TLIM).GT.0.) GO TO 650
```

```
      IF(IPRCT-ICT) 650,650,665
  650 CONTINUE
      QINP=QIN/3600.
      DO 655 I=1,NPF
  655 TX2(I)=TX2(I)-460.
      XISDTH(1)=XISOTH(1)-460.
      XISOTH(2)=XISOTH(2)-460.
      PLPSI=PL*2116.217/144.
      IF(PLPTX.GT.0.) GO TO 657
      WX=FWX(IFTC)+(FWX(IFTC+1)-FWX(IFTC))*TFTC
      AOTX=AOT(IFTC)+(AOT(IFTC+1)-AOT(IFTC))*TFTC
  657 WRITE(20,40) T,OTS,FCONV,FRAD,VELX,QCONX,QRADX,AOTX,XMOG(1),XMDC,
     1            XMDT,XLSTI,SDOTT,XMDS
      WRITE(20,45) QINP,QRERAD,TQSUBL,ALPHA,QHW,QSIO2,TQDXID,BCOF,QWB,
     1            TQIN,TQRERA,G,QBLOCK,TQHW,DELH,PLPSI,QSUBL,TQRAOX,
     2            HTX,PLPT,QDXID,TQBLDC,RHOST,WX
      IF(SPRINT.LT.1.)GO TO 665
      IF(SPRINT.EQ.1.) GO TO 660
      WRITE(20,50)
      GO TO 665
  660 WRITE(20,55)
  665 T=T+OTS
      IF((T-OTS).EQ.0.) GO TO 675
      IF((T-TLIM).GT.0.) GO TO 675
      IF(IPRCT-ICT) 675,675,690
  675 WRITE(20,60) T
      KKV=KKV+1
      DO 680 I=1,NP
  680 XVPNT(I)=XV(I)*12.+XLSTI
      WRITE(20,65) (XVPNT(I),TX2(I),DEN(I),THETA(I),XMDG(I),XMCOKE(I),
     1             SMCOKE(I),P(I),I=1,NP)
      IJ=NP+1
      WRITE(20,70) (TX2(I),I=IJ,NPF)
C-----------------------------------------------------------------
C     WRITE(20,682)
C 682 FORMAT(' BEFORE BIG MULTI CALL'//)
C-----------------------------------------------------------------
      CALL BET(XTCLF,TTCL,NXTCL,XV,TX2,NP,XLSTV,IBGN)
C     ********
      CALL RITE(XTCL,TTCL,NXTCL,IBGN)
C     *********
      CALL ISOTHM(XV,THETA,XISOTH(3),NP,Y5,IP1,LP1)
C     ***********
      CALL ISOTHM(XV,THETA,XISOTH(4),NP,Y6,IP9,LP9)
C     ***********
C-----------------------------------------------------------------
C     WRITE(20,683)
C 683 FORMAT(' AFTER BIG MULTI CALL'//)
C-----------------------------------------------------------------
      Y5=Y5*12.+XLSTI
      Y6=Y6*12.+XLSTI
      WRITE(20,75) XISOTH(1),XMAXI,XISOTH(2),XMAX2,XISOTH(1),Y3,
     1   XISOTH(3),Y5,XISOTH(2),Y4,XISOTH(4),Y6
      DELOSS=Y6-(RHOC/RHOV)*(Y5-XLSTI)-((RHOC+RHOV)/(2.*RHOV))*(Y6-Y5)
      EQUTH=(VL*12.)-DELOSS
      WRITE(20,80) DELOSS,EQUTH
      DO 685 I=1,NPF
  685 TX2(I)=TX2(I)+460.
      XISOTH(1)=XISOTH(1)+460.
      XISOTH(2)=XISOTH(2)+460.
```

```
C
      ICT=0
  690 CONTINUE
      SQCONX=QCONX
      IF(T-TLIM) 300,300,695
  695 VL=VL*12.
      BL=BL*12.
      DO 700 I=1,14
  700 TTCL(I)=TTCL(I)+460.
C     IF(NPLOT.GT.0) CALL TPLOT(T-OTS,XLSTI,TX2,Y3,Y4,Y5,Y6,SOOTT,QCONX,
C    1                QRAOX,QHW,QWB,XMOT,TTCL,NP,NPPCAS)
      NCASE=NCASE+1
C
      TX2(NP)=TX2(NP)-460.
      XISOTH(1)=XISOTH(1)-460.
      XISOTH(2)=XISOTH(2)-460.
      TLNM=TLNM-460.
      TFNM=TFNM-460.
      WRITE(20,85) NCASE
      WRITE(20,90) LINE1,LINE2,LINE3
C FORTRAN FUNCTION AVAILABLE AT ORAPER
      IUSEO = ITIME(IOUM)
C     **********
C-----------------------------------------------------------------------
C     WRITE(20,702)
C 702 FORMAT(' ITIME CALLEO'//)
C-----------------------------------------------------------------------
      SEC=IUSEO/100.
      IF(TEMPW.GT.-1.0E6) GO TO 705
      WRITE(20,95) VL,NP,VEL(1),,SEC,NPPCAS
      GO TO 710
  705 WRITE(20,100) VL,NP,VEL(1),TEMPW,SEC,NPPCAS
  710 WRITE(20,105) QCONT(NTRAPT),QTCL,QRAOT(NTRAPT),QTRL,
     *QTOTAL(NTRAPT),QTCRL
      WRITE(20,110) QCMAX,QCMAXT,QRMAX,QRMAXT,QCANR,QCANRT
      WRITE(20,115) QCONM,TCONM,QRAOM,TRAOM,QTM,TQTM
      WRITE(20,120) TQHW,TQRAOX,TQRERA,TQBLOC,TQSUBL,TQIN,TQQXID
      WRITE(20,125) XISOTH(1),XMAXI,XISOTH(1),TXMAX,XISOTH(2),XMAX2,
     1XISOTH(2),TXMAX2,TFNM,TIFNM,TLNM,TILNM,TX2(NP),TLIM
      WRITE(20,130) XLSTI
C WRITE(16) IS CUTOUT ELIMINATING SUMARRY CASE
C     WRITE(16) (H1(I),I=1,12),(HEAO2(I),I=1,12),(HEAO3(I),I=1,12),(H3(I
C    1),I=1,12),VL,NP,VEL(1),IMIN,ISEC,NPPCAS,QCONT(NTRAPT),QTCL,
C    2QRAOT(NTRAPT),QTRL,QTOTAL(NTRAPT),QTCRL,QCMAX,QCMAXT,
C    3QRMAX,QRMAXT,QCANR,QCANRT,QCONM,TCONM,QRAOM,TRAOM,QTM,TQTM,
C    4XISOTH(1),XMAXI,TXMAX,XISOTH(2),XMAX2,TXMAX2,TLNM,TILNM,TFNM,
C    5TX2(NP),TLIM,XLSTI,TEMPW,TQHW,TQRAOX,TQRERA,TQBLOC,TQSUBL,
C    6TQIN,TQQXIO
C
      XISOTH(1)=XISOTH(1)+460.
      XISOTH(2)=XISOTH(2)+460.
C NOTE NPLOT WILL ALWAYS BE <=0. WHICH DIRECTS YOU TO 200-RESET
      IF (NPLOT.LE.0) GO TO 200
C
C IN VIEW OF THE ABOVE COMMENT, THE FOLOWING SEQUENCE OF STEPS
C IS BEING CUT OUT SINCE THEY DEAL WITH PLOTTING AND THEY ARE
C A SOURCE OF VS FORTRAN COMPILER ERROR
C
C     NPCAS(NCPLTC)=NPPCAS
C     NCPLTC=NCPLTC+1
```

```
C      IF(NCPLTC.GT.NCPLOT) GO TO 715
C      GO TO 200
C 715 ENDFILE 10
C      REWIND 10
C      WRITE(20,135) (I,NPCAS(I),I=1,NCPLDT)
C      DO 720 I=1,NCPLOT
C
C DO NOT CALL THIS SUBROUTINE (MORE)
C
C 720 CALL MORE(NPCAS(I),DXPLDT)
C
C DO NOT CALL THIS SUBROUTINE (CCP)
C
C      CALL CCP(6)
C      GO TO 200
C
C 725 ENDFILE 16
C      REWIND 16
  725 DO 740 K=1,NCASE
C      READ (16) (H1(I),I=1,12),(HEAD2(I),I=1,12),(HEAD3(I),I=1,12),(H3(I
C     1),I=1,12),VL,NP,VEL(1),IMIN,ISEC,NPPCAS,QCONT(NTRAPT),QTCL,
C     2QRADT(NTRAPT),QTRL,QTOTAL(NTRAPT),QTCRL,QCMAX,QCMAXT,
C     3QRMAX,QRMAXT,QCANR,QCANRT,QCONM,TCONM,QRAOM,TRADM,QTM,TQTM,
C     4XISOTH(1),XMAXI,TXMAX,XISOTH(2),XMAX2,TXMAX2,TLNM,TILNM,TFNM,
C     5TX2(NP),TLIM,XLSTI,TEMPW,TQHW,TQRADX,TQRERA,TQBLOC,TQSUBL,
C     6TQIN,TQDXID
      WRITE(20,85) K
C CUTOUT HEADINGS
C      WRITE(20,90) (H1(I),I=1,12),(HEAD2(I),I=1,12),(HEAD3(I),I=1,12), (
C     1H3(I),I=1,12)
      IF(TEMPW.GT.-1.0E6) GO TO 730
      WRITE(20,95) VL,NP,VEL(1),SEC,NPPCAS
      GO TO 735
  730 WRITE(20,100) VL,NP,VEL(1),TEMPW,SEC,NPPCAS
  735 WRITE(20,105) QCONT(NTRAPT),QTCL,QRADT(NTRAPT),QTRL,QTOTAL(NTRAPT)
     *,QTCRL
      WRITE(20,110) QCMAX,QCMAXT,QRMAX,QRMAXT,QCANR,QCANRT
      WRITE(20,115) QCONM,TCONM,QRAOM,TRADM,QTM,TQTM
      WRITE(20,120) TQHW,TQRADX,TQRERA,TQBLDC,TQSUBL,TQIN,TQDXID
      WRITE(20,125) XISOTH(1),XMAXI,XISOTH(1),TXMAX,XISOTH(2),XMAX2,
     1XISDTH(2),TXMAX2,TFNM,TIFNM,TLNM,TILNM,TX2(NP),TLIM
  740 WRITE(20,130) XLSTI
C      REWIND 16
  750 STOP
      END
```

```
      BLOCK DATA MAINDA
C-----------------------------------------------------------------------
C THIS DATA STATEMENT ASSIGNS MANY PARAMETERS WHICH TEND TO REMAIN
C CONSTANT DURING VARIOUS COMPUTER RUNS.  ALL THE PROPERTIES FOR THE
C BACKUP MATERIALS ARE SPECIFIED IN THE STATEMENT.  THE CONDUCTIVITY
C AND SPECIFIC HEAT OF THE VIRGIN AND CHAR MATERIAL ARE ALSO ASSIGNED
C HERE.  NOTE THAT THE VALUES CURRENTLY IN THIS STATEMENT ARE FOR
C THE MATERIAL FIREX 2373.  ALSO NOTE THAT THE CONDUCTIVITY HAS BEEN
C ALTERED FOR THE VIRGIN MATERIAL TO REFLECT THE PHENOMENA OF INTU-
C MESCENCE WHICH FIREX EXHIBITS WHEN EXPOSED TO LOW HEAT FLUXES.
C-----------------------------------------------------------------------
C
C-----------------------------------------------------------------------
C THE BACKUP MATERIALS ARE THREE 1.0 INCH AIR GAPS
C-----------------------------------------------------------------------
C
      COMMON/YYZY/ QSIC(50), RHDCF, SN2, XB2, CA2, HV2
      COMMON /ABPRDP/ RHD(50)
      COMMON /BACKUP/ XNPM(12),RHOBX(12),XBM(12),EMBB(12),EMFB(12)
     1      , NKPB(12),NCPB(12),TXK(20,12),XK(20,12),TCP(20,12),NPM(12)
     2      , CPX(20,12),GAPX(12),FTEST(12),BTEST(12),H(12),XKB(10,12)
     3      , CPB(10,12),DXB(12)
      COMMON /TEMPS/ TEMOI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
     1      , TUL2(50),TY(200),TEMPI,TXO,SURTEM
      COMMON /CDEFFS/ A(200),B(200),C(200),D(200),AB(10,12),BB(10,12)
     1      , CB(10,12),DB(10,12),SB(10,12),RB1(10,12),RB2(10,12),R(50)
     2      , S(50),INT
      COMMON /ABLATS/ XMDG(50),TABL,TCHAR,RHOV,RHDC,TREC,XLDST,SDOTDS
     1      , SOOT,XMOC,XMT
      COMMON /INDIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      COMMON /TIMES/ TINT,TLIM,T,DT
      COMMON /FNTBCK/ FBLOW,EMV,EMC,H300,TEST2,TENV,QIN,HENV,FENV
     1      , QLDSS,DHC,HXX(12),HX(50),TW(50)
      COMMON /HSPARA/ DX,     TL,VL,BL,OMP,VPT
      COMMON /FIXPRO/ CHARK,CHARC,ABLK,ABLC
      COMMON /TURBU/ WX,RTR,PLPT,SHAPEF
      COMMON /TRAJ/ TIME(300),QCONC(300),QRAD(300),VEL(300),ALT(300)
     1      , QCON(300),NTRAPT,FCONV,FRAD
      COMMON /FIXERS/ I1,I2,I3,I4,I5,I6
      COMMON /JUNK/ ERR1,ERR2,ERR3,ERR4
      COMMON /INPUTS/ NTURBT,MMM,LAST,ITHIN,TFACT,TSUBL,IPRESS,NREAD
     1      , RHOS,XMWG,TABL2,H1(12),HEAD2(12),HEAD3(12),H3(12),DXPLDT
     2      , FBLDWL,FBLDWT,FFLAG,FV,  TTABLE(20),DELTT(20),IPRC(20)
     3      , NPTT,TS(50),SR(50),QCONX,QRADX,NHP,NPR,NREC,RTEST,SRM1
     4      , SRM2,SRB1,SRB2,KLLL,TV,PLPTX
      COMMON /ARRH/ THETA(50),AP,XB,SN,CA
      COMMON /PRES/ P(50),ALFAV,ALFAC,BETAV,BETAC,Z
      COMMON /PLTVAR/ NCPLTC,NCPLOT,NPLOT,NPCAS(25),NPPCAS,TTCL(15)
     1      , TTCLPL(15),XTCLF(15),XTCL(15),NXTCL,XISDTH(4),Y3,Y4,Y5,Y6
     2      , XV(50),XVPNT(50),XVT(50),XLSTI,XMDT
      COMMON/TABS/ TNODE(50),DCHAR(50),ITABLE(9,10),ITAB(9,6)
     1            , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2            , IVIRG1,IVIRG2,TREAD,IERROR,ITABND,AINPUT(9),W(50)
     3            , ISTART,IENO,ANSWR(350)
      COMMON/RESCUT/ TCOFF(10),XRECES(10),XVNEW(50)
```

```
      COMMON /TRBATS/ PLA(300),TLA(300),HLA(300),VLA(300),TTA(300)
      COMMON /FACTRS/ AOT(300),FC(300),FR(300),FPLPT(300),SOVR,PHI,
     1                FWX(300),WX1,WX2
      COMMON /OREF/ OCONT(300),ORAOT(300),OTOTAL(300),OTCL,OTRL,OTCRL,
     1              OCMAX,OCMAXT,ORMAX,ORMAXT,OCANR,OCANRT
C ENTHALPY TABLE
      OATA (HX(I), I =1,42)/ O., 342.9, 449.7, 617.2,791.0,978.,1113.,
     11200., 1300.,1400.,1500., 1600., 1700.,1800.,1900., 2000.,2100.,
     2 2200.,2300.,2400.,2500.,2600., 2700., 2800.,2900.,3000.,3100.,
     3 3200.,3300.,3400., 3500., 3600.,3700.,3800.,3900.,4000.,4100.,
     4 4200., 4300., 4400.,4500., 4600./,
C TEMPERATURE TABLE CORRESPONOING TO ENTHALPY TABLE
     5  (TW(I),I =1,42) / O.,1400., 1800., 2400.,3000.,3600.,4000.,
     6  4224., 4486., 4723.,4936.,5127., 5299.,5454.,5596.,5728.,5851.,
     7  5968., 6078., 6186., 6291.,6395., 6497., 6597., 6699., 6805.,
     8  6918., 7050., 7175., 7350., 7480., 7630., 7800., 7970.,8120.,
     9 8300., 8500.,8700.,8850.,9000.,9150.,9270./
C
C     502 BEST FIT PROPERTIES
C
C  99998 - K(C)   99997 - CP(C)   99996 - K(V)   99995 - CP(V)
C
      OATA (TABLES(I),I=1,84)  /99998.,-1.E35,460.,760.,1460.,1860.,
     1            2060.,2660.,2860.,3710.,3960.,4260.,4860.,5010.,
     2            5060.,6000.,1.E35,.046,.046,.030,.030,.060,.060,.060,
     3            .060,.060,.060,.060,.060,.060,.060,.060,.060,99997.,
     4            -1.E35,1460.,2460.,4960.,5460.,1.E35,.37,.37,.412,
     5            .412,.46,.46,99996.,-1.E35,460.,560.,660.,760.,860.,
     6            1260.,1460.,1.E35,.199,.199,.199,.141,.083,.018,.018,
     7            .018,.018,99995.,-1.E35,0.,560.,660.,760.,860.,960.,
     8            1060.,1.E35,.47,.47,.47,.47,.47,.47,.47,.47,.47/
      OATA (ITAB(1,I),I=1,6)  /99998, 1,33,14,1,2/,
     1     (ITAB(2,I),I=1,6)  /99997,34,46,4,1,2/,
     2     (ITAB(3,I),I=1,6)  /99996,47,65, 7,1,2/,
     3     (ITAB(4,I),I=1,6)  /99995,66,84, 7,1,2/
      OATA (AINPUT(I),I=1,9)  /O.,O.,-99998.,-99997.,-99996.,-99995.,
     1                         .5,180.,12000./, ITABNO /4/
C TEMPERATURE VALUES FOR SURFACE RECESSION
      OATA(TS(I), I =1,3) / 0.0,2000.0,4000./
C SURFACE RECESSION VALUES
      OATA(SR(I), I =1,3) / 0.0,0.0,0.0/
C NUMBER OF NOOES IN THE BACKUP MATERIAL
      OATA XNPM(1) / 3./,XNPM(2) / 3./,XNPM(3)/ 3./
C NUMBER OF ENTRIES IN XK ANO CPX TABLES
      OATA NKPB(1) / 6/,NKPB(2) / 6/,NKPB(3)/ 6/,
     1     NCPB(1)/ 3/,NCPB(2)/ 3/,NCPB(3)/ 3/
C THERMAL CONOUCTIVITY OF BACKUP MATERIALS/ TEMPERATURES OF XK'S
      OATA ((XK(I,J),I=1,6),J=1,3) /.013,.016,.018,.025,.030,.041,
     1 .013,.016,.018,.025,.030,.041,.013,.016,.018,.025,.030,.041/
     2     ((TXK(I,J),I=1,6),J=1,3) /O.,560.,660.,960.,1260.,1960.,
     3     O.,560.,660.,960.,1260.,1960.,
     4     O.,560.,660.,960.,1260.,1960./
C SPECIFIC HEAT OF BACKUP MATERIALS/ TEMPERATURES OF CPX'S
      OATA ((CPX(I,J),I=1,3),J=1,3) /.239,.248,.277,.239,.248,.277,
     1.239,.248,.277/
     2     ((TCP(I,J),I=1,3),J=1,3) /O.,960.,1960.,
     3     O.,960.,1960., O.,960.,1960./
C OENSITY OF NTH BACKUP MATERIAL
      OATA RHOBX(1)/ .071/,RHOBX(2)/ .071/,RHOBX(3)/ .071/
C FILM COEFFICIENT/ WIOTH OF GAP/ MOOE OF HT ON FRONT ANO BACK SURFACES
```

```
C OF BACKUP MATERIALS (CONDUCTION ONLY IS '0')
      DATA  H(1)/ 0./, H(2)/ 0./, H(3)/ 0./,
     1      GAPX(1)/0./,GAPX(2)/0./,GAPX(3)/0./,
     2      FTEST(1) /0./,FTEST(2) /0./,FTEST(3) /0./,
     3      BTEST(1)/ 0./,BTEST(2)/ 0./,BTEST(3)/ 0./
C THICKNESS OF NTH BACKUP/EMISSIVITY, FRONT + BACK/ISOTHERM TEMPERATURES
      DATA XBM(1)/ 1.000/,XBM(2)/ 1.000/,XBM(3)/ 1.000/,
     1      EMFB(1)/ .65/,EMFB(2)/ .65/,EMFB(3)/ .65/,
     2      EMBB(1)/ .65/,EMBB(2)/ .65/,EMBB(3)/ .65/
C ISOTHERM TEMPERATURES AND LOCATION OF PENETRATION
      DATA (XISOTH(I),I=1,4) / 660., 860., .1, .9/
      END
```

```
C***
C*** X   IS S/R
C*** Y    IS H/RTO
C*** ANS  IS A/AO
C*** IREG IS AN ERROR FLAG
C***
      SUBROUTINE MOLA(X,Y,ANS,IREG)
      DIMENSION A(192)
      DATA (A(I),I=1,192)/50.,50.,4.,3.,1.,3.,3*0.,-.0032195384,.149306
     1 18,.024543126,.58719964,-.018700624,-.12679730,-.0047674354,.8893
     2 2236,.00078285889,-.10835613,.56441762,.37036180,8.,4.,2.,3.,-.04
     3 0898376,.13951988,-.27615870,.051828567,-.12518611,.17224281,.029
     4 639706,.052193854,-.034404423,.0036351444,-.18116469,.45279737,-.
     5 57587609,.33862799,-1.3483524,12.,4.,2.,2.,-.011243653,-.50236486
     6 ,.028778314,-.53050821,.18734878,.24768639,4*0.,-.046173894,-1.71
     7 84643,-.14120287,-2.0878814,.40400907,22.,8.,1.,1.,3*0.,.27019527
     8 ,.087105078,.35310403,7*0.,.80559313,.12506346,55.,29.,1.,1.,3*0.
     9 ,.36655108,.094702449,.43541615,7*0.,1.0622964,.085103548,115.,45
     1 .,1.,2.,3*0.,-.053736147,.38382141,.56190424,4*0.,.11971267,.2139
     2 1352,-.033762414,.32270364,.56227585,275.,135.,1.,3.,3*0.,.976585
     3 95,.021635273,.70806018,-.31509382,-.085827964,.028840452,-.01119
     4 6820,.49895458,-.28510509,.031935473,1.8024960,-.11480061,550.,16
     5 0.,1.,2.,3*0.,-.72838160,.46232249,.89758565,4*0.,-.20728528,.152
     6 56155,-.037554800,-.57795031,.41716145,850.,160.,1.,1.,3*0.,-.647
     7 29837,.086476954,.98811448,7*0.,-.55654570,.058113803,1500.,500.,
     8 2.,2.,-2.9423586,-.13541076,.56268965,1.8977468,2.3715247,1.46999
     9 63,4*0.,-3.4056509,.38232701,.39935799,2.8341377,1.8337715/
C
      CALL TESTH(X,Y,N124,IREG)
C     **********
      IF(IREG-1)106,106,52
   52 CALL COMMOL(A,N124,X,Y,Z)
C     ***********
      ANS=EXP(2.3025851*Z)
      IF(ANS-10.)106,106,101
  101 ANS=9.5
  106 RETURN
      END
```

```
C***
C*** W    IS LDG(P/PO)
C*** X    IS S/R
C*** ANS  IS H/RTO
C*** IREG IS AN ERRDR FLAG
C***
      SUBRDUTINE MDLH(W,X,ANS,IREG)
      DIMENSIDN D(9),B(211)
      DATA (D(I),I=1,9)/30.,34.,40.,46.,54.,66.,75.,105.,120./
      DATA (B(I),I=1,163)/0.,1.,22.,8.,1.,3.,3*0.,.27705970,.96528532,.
     1 33963361,-.00046574169,-.0040482061,-.010461855,-.0065518644,.008
     2 6161097,.053813741,.080578914,-.028200442,-.086349097,31.,3.,1.,3
     3 .,3*0.,.27741402,.35801125,1.4336617,-.00061979172,-.0021073096,-
     4 .0017536359,-.00030437482,.0048221948,.014964288,.011818412,.0188
     5 50715,.022652230,37.,5.,1.,3.,3*0.,.25398163,.52741571,1.9710287,
     6 -.00082790533,-.0043204605,-.0092904068,-.010012783,-.00058422190
     7 ,.011305387,.022774231,.036940874,.095871923,43.,5.,1.,3.,3*0.,.2
     8 3024026,.29862855,2.2282276,.000076812456,-.0075547092,-.02265672
     9 0,-.020508249,.0019404355,-.029600215,-.035441447,.061998174,.003
     1 9092319,50.,6.,1.,3.,3*0.,.010634740,.23986720,2.5779744,-.000463
     2 44986,-.0028717178,-.0058313624,-.0041905119,.0015071233,.0076500
     3 227,.0099612338,-.041780586,.022298730,60.,8.,2.,2.,-.024144609,-
     4 .14736552,-.081078878,-.25708774,.50948618,2.8427847,4*0.,-.00669
     5 78058,-.055558702,-.037666146,-.13441391,.10779956,72.,6.,1.,2.,3
     6 *0.,-.30558436,-.060489230,3.1096929,4*0.,.0037345606,.0094279706
     7 ,.0059743084,-.13780027,-.055336496,85.,20.,2.,1.,.0015831288,.00
     8 15210631,-.021064008,.069168293,.81191642,3.2991879,7*0.,-.010969
     9 054,.16785084,110.,10.,1.,3.,3*0.,-1.4885346,-.79483058/
      DATA (B(I),I=164,211)/3.7508695
     1 ,-.00086604638,-.0022915171,-.0046611641,-.0028679115,.0003396599
     2 4,.0044027079,-.0035649683,-.49030054,-.27883162,37.,5.,1.,3.,3*0
     3 .,.44115113,.92686523,1.9665635,.00058376187,.0037858373,.0082954
     4 080,.0038932475,-.010183489,-.033293369,-.023318402,.13355665,.29
     5 776691,43.,5.,1.,3.,3*0.,.10701313,.45687535,2.3111196,-.00029903
     6 547,-.0012387784,-.0013394298,-.0010879150,.0021927292,.006726473
     7 3,.0062897753,-.017360511,.095276562/
      IF(-6.-W)72,72,220
   72 IF(5.-W)220,103,103
  103 IF(X-13.)220,110,110
  110 IF(X-120.)114,114,220
  114 L=3
      DO 137 K=1,9
      IF(X-D(K))141,141,133
  133 L=L+19
  137 CONTINUE
  141 IF(L-41)172,146,153
  146 IF(W+.2)172,165,165
  153 IF(L-60)160,160,172
  160 IF(W+2.3)172,165,165
  165 L=L+133
  172 CALL COMMOL(B,L,W,X,Y)
C     **********
      ANS=EXP(Y*2.3025851)
      IREG=2
      GO TO 222
  220 IREG=1
  222 RETURN
      END
```

```
C***
C*** X    IS S/R
C*** Y    IS H/RTO
C*** ANS  IS LOG(P/PO)
C*** IREG IS AN ERROR FLAG
C***
      SUBROUTINE MOLP(X,Y,ANS,IREG)
      DIMENSION P(192)
      DATA (P(I),I=1,170)/50.,50.,4.,3.,2.,1.,.15005431,-11.875372,.186
     1 01692,-21.633755,-5.0224106,-11.257093,7*0.,-.0067242968,.5464345
     2 0,8.,4.,2.,1.,4.8246612,-8.5980114,.093795043,-19.432002,-3.19525
     3 67,-10.198613,7*0.,-.22196817,.38821169,12.,4.,2.,1.,8.8698867,-2
     4 .5267113,-.040858173,-17.792731,-.49121647,-9.5728967,7*0.,-.4083
     5 1557,.10633168,22.,8.,2.,3.,-20.111381,-2.1441838,.014443150,-29.
     6 454863,-.47192620,-8.5112371,.25523739,.0066484889,.0033863644,.0
     7 015706618,.29212782,.0079289807,-.00260680,1.0278853,.12630380,55
     8 .,29.,2.,2.,-4.8634801,-5.7702261,.18758816,-21.577115,-.87969647
     9 ,-6.3939887,4*0.,.075998763,.15656807,.021045125,.40420838,.38169
     1 280,115.,45.,2.,3.,-14.307050,-3.6724161,.13750957,-21.095445,-.0
     2 70520782,-4.1064793,-.12628849,-.19177802,-.000045377713,.0067747
     3 753,-.17712703,.027519558,.0015860428,.87906794,.30647355,275.,13
     4 5.,2.,2.,-20.075969,1.1024015,.026282217,-16.104741,1.5155751,-1.
     5 1690305,4*0.,.050928801,.29769415,.00077288959,1.5256376,.2426488
     6 5,550.,160.,2.,1.,-1.8426956,-2.4064009,.11494271,-10.937820,1.38
     7 80114,1.3371699,7*0.,.26456615,.33361590,850.,160.,2.,3.,-6.51518
     8 34,-.85195421,.054337316,-6.8468864,.94695076,2.3221757,-.5349839
     9 9,.26778936,-.044538904,.0021455882,.98320726,-.25476113/
      DATA (P(I),I=171,192)/.041036116,.21507674,.31155051,1500.,500.,
     1 2.,2.,-10.103526,6.6634563,-1.0278980,.48045903,-1.7843572,2.4233
     2 978,4*0.,.29619502,.053797980,-.11794996,.95870246,-.30898900/
C
      CALL TESTH(X,Y,N74,IREG)
C     **********
      IF(IREG-1)61,61,45
   45 CALL COMMOL(P,N74,X,Y,ANS)
C     ***********
   61 RETURN
      END
```

```
C***
C*** SOR  IS S/R
C*** HORT IS H/RTO
C*** ANS  IS LOG(P/PO)
C*** IREG IS AN ERROR FLAG
C***
      SUBROUTINE MOLR(SOR,HORT,ANS,IREG)
      OIMENSION A(192)
      DATA (A(I),I=1,167)/50.,50.,4.,3.,2.,1.,.29646067,-12.029348,.141
     1 09302,-21.556625,-5.4563379,-11.316583,7*0.,-.013484723,.55334227
     2 ,8.,4.,2.,1.,10.370284,-9.9398482,.093205445,-16.650190,-4.148325
     3 0,-10.551169,7*0.,-.47741818,.44562816,12.,4.,2.,1.,28.357261,-.4
     4 0220242,-.091946872,-8.5069814,.44762202,-10.089678,7*0.,-1.30576
     5 21,-.0052874757,22.,8.,2.,3.,-20.515034,-2.2545360,.015611412,-30
     6 .238408,-.70234767,-9.2212898,.35028502,.033535686,.010294011,.00
     7 18341365,.40126774,.032551723,.0016893023,1.0849856,.13074092,55.
     8 ,29.,2.,2.,-17.065362,-1.8243845,.027389882,-26.066901,-.11273894
     9 ,-7.3122123,4*0.,.12676889,.15670133,.0055456298,1.0205623,.21108
     9 427,115.,45.,2.,3.,47.004757,-16.021931,.39136805,-3.4926704,-3.5
     1 464860,-5.3298536,1.3005490,-.57583006,.080704954,.0042520642,-.3
     2 5475548,-.14760870,.072690447,-2.5895288,.85700048,275.,135.,2.,3
     3 .,17.420013,-8.0508205,.40903702,-10.889706,-.10331446,-2.6810765
     4 ,.91536506,-.44954500,.056883407,-.0078941843,-.46389858,-.044033
     5 323,.082227159,-1.0802966,.63717741,550.,160.,2.,1.,-.52664526,-1
     6 .9193044,.040457103,-10.998347,.63541058,-.51776785,7*0.,.1376570
     7 4,.27443512,850.,160.,2.,3.,6.7873925,-.92691880,.0049465705,-10.
     8 354406,.51247015,.57436892,.10119706,-.057801836,.0072531624/
      DATA (A(I),I=168,192)/.00021341241,
     9          -.29508863,.039002554,.0012492809,-.44301206,.11096111,1
     9 500.,500.,2.,3.,2.4082057,.69779795,-.21986558,-3.5450464,-.41979
     1 069,-.13207427,-.0019447663,-.0049813671,.014962087,-.00088754904
     2 ,.23275979,-.28026272,.017554770,-.99050961,.30663019/
      CALL TESTH(SOR,HORT,I74,IREG)
C     **********
      IF(IREG.EQ.1)GO TO 60
      CALL COMMOL(A,I74,SOR,HORT,ANS)
C     ***********
   60 RETURN
      END
```

```
C***
C*** W    IS LOG(P/PO)
C*** Y    IS H/RTO
C*** ANS  IS S/R
C*** IREG IS AN ERROR FLAG
C***
      SUBROUTINE MOLS(W,Y,ANS,IREG)
      OIMENSION S(192)
      DATA (S(I),I=1,149)/0.,1.,4.,3.,2.,3.,-.00080561372,-.069087518,.
     1 027464886,-.11380348,.95169019,1.3815255,-.0000057990656,-.000123
     2 00780,.00011636034,.0012208080,-.00071210995,-.031772602,.0118874
     3 93,-.052296548,.65468922,8.,4.,2.,1.,.000503664,-.0012816317,-.00
     4 59983993,-.11930272,.11287569,1.4231668,7*0.,-.057251211,.0581412
     5 2,12.,4.,1.,2.,3*0.,-.10774019,.05807095,1.4463519,4*0.,-.0002013
     6 7394,.00022152799,.0019518188,-.049714580,.026980282,22.,8.,2.,3.
     7 ,.0027192237,-.033931899,.014176636,-.022802602,-.2479084,-.39615
     8 334,.0000035001106,-.000081170565,.00034046708,-.00500902l,-.0000
     9 5586814,.00086677974,.0025764335,-.058649747,.69620994,55.,29.,2.
     1 ,2.,.00083174503,-.017794792,.012031825,-.044492627,-.028063518,-
     2 .31922865,4*0.,-.00020568307,.0082727049,-.019137651,-.0096276364
     3 ,.25046296,115.,45.,2.,2.,-.0056251369,-.0015950635,.0011525511,-
     4 .07943472,.03401695,-.23108108,4*0.,.0019412961,-.0039465752,-.01
     5 6248866,.10844722,.086590989,275.,135.,2.,3.,-.00039528921,-.0148
     6 58414,.000014723618,-.069546961,.10612579,-.080804506,.0001014453
     7 7,.00046518281,-.00016907078,.008022368,.0010915855,.0032314882,-
     8 .012099992,.016178205,.056239683,550.,160.,2.,2.,-.00086049623,-.
     9 02776368,.010558864,-.088218134,.12402428,.1193478,4*0./
      DATA (S(I),I=150,192)/.00093089117,-.00039895385,-.0013731034,.02
     1 1879948,.22819871,850.,160.,2.,2.,.027159346,-.055317935,.0217328
     2 82,-.17316771,.16235389,.27050669,4*0.,-.0017015074,.025122763,.0
     3 002445801,-.2487639,.33867764,1500.,500.,1.,3.,3*0.,-.30922899,-1
     4 .455907,1.8756767,.00007460909,-.00026785349,-.00075011575,-.0040
     5 865079,-.00084256838,-.0090684213,.026295107,-.13858356,-.7969430
     6 5/
      CALL TESTH(W,Y,N140,IREG)
C     **********
      IF(IREG-1)120,120,52
   52 CALL COMMOL(S,N140,W,Y,X)
C     ***********
      N140=N140+1
      IF(N140-59)74,74,105
   74 ANS=EXP(X*2.3025851)
      GO TO 120
  105 IF(N140-173)112,112,74
  112 ANS=X*50.+50.
  120 RETURN
      END
```

```
C***
C*** X    IS S/R
C*** Y    IS H/RTO
C*** ANS  IS T
C*** IREG IS AN ERROR FLAG
C***
      SUBROUTINE MOLT(X,Y,ANS,IREG)
      DIMENSION T(192)
      DATA (T(I),I=1,183)/50.,50.,4.,3.,2.,1.,-.001662012,-.00030083209
     1 ,.046179467,-.0042974158,1.6563552,2.4957474,7*0.,-.0011127006,.5
     2 3431056,8.,4.,1.,1.,3*0.,.0067799737,.96965414,2.7914059,7*0.,.00
     3 24459562,.27194367,12.,4.,1.,1.,3*0.,-.0070861052,.67589623,2.957
     4 5481,7*0.,-.002380321,.18296218,22.,8.,2.,1.,-.10841575,-.2007499
     5 9,-.030015981,-3.8311066,.44841953,3.1783501,7*0.,-1.172013,.1004
     6 7983,55.,29.,2.,2.,10.510419,.78019581,.07377469,8.0537558,1.5265
     7 471,3.311009,4*0.,3.2439108,.29525752,.012016203,2.5402056,.43970
     8 633,115.,45.,2.,2.,6.9650128,2.9959483,.099214637,8.5056773,2.348
     9 8217,3.5515688,4*0.,2.0791532,.8292544,.016441181,2.4936922,.6240
     16866,275.,135.,2.,3.,2.102422,1.2079036,-.54560532,4.8029687,.7061
     2 6618,3.7680081,.026794453,.016865589,-.040698219,.0037372526,.696
     3 08228,.31656604,-.14622854,1.4458192,.15328036,550.,160.,2.,3.,1.
     4 1622911,2.4200366,4.0108106,-3.5603333,2.3041078,4.0077135,.18420
     5 427,.11553482,.11218739,-.030143326,.033296111,.64585002,.9835687
     6 7,-.75069059,.53856768,850.,160.,2.,3.,-1.5674925,3.5878439,1.863
     7 4423,-.15969706,.88403848,4.2222854,-.076696683,.091025232,.03096
     8 5581,-.0068679561,-.35160837,.88944428,.443366,.076640642,.189604
     9 13,1500.,500.,1.,3.,3*0.,7.5792861,-9.7314346,2.9826061/
      DATA (T(I),I=184,192)/-.446325,.46100429,-.13524719,.0058322903,1
     1 .362303,-1.1507226,.21638788,.7264903,-1.8320955/
      CALL TESTH(X,Y,N110,IREG)
C     **********
      IF(IREG-1)40,40,50
   50 CALL COMMOL(T,N110,X,Y,TT)
C     ***********
      ANS=EXP(TT*2.3025851)
   40 RETURN
      END
```

```
C
C     THIS SUBROUTINE CALCULATES THE HEATING RATE DUE TO COMBUSTION
C     IT IS ASSUMED THAT OXYGEN AND CARBON REACT  TO FORM CO ONLY.
C
      SUBROUTINE OXIDAT(XMDO,QOXID)
      COMMON /FNTBCK/ FBLOW,EMV,EMC,H3OO,TEST2,TENV,QIN,HENV,FENV
     1     , QLOSS,DHC,HXX(12),HX(5O),TW(5O)
C
      QOXID=XMDO*DHC/36OO.O
      RETURN
      END
```

```
C     THIS SUBROUTINE OETERMINES THE PHYSICAL PROPERTIES OF THE
C       HEAT SHIELO STRUCTURE
      SUBROUTINE PROP (NTERR)
C
      OIMENSION CP(50),YK(50),CPGAS(50),HV(50)
      COMMON /ABPROP/ RHO(50)
      COMMON /BACKUP/ XNPM(12),RHOBX(12),XBM(12),EMBB(12),EMFB(12)
     1      , NKPB(12),NCPB(12),TXK(20,12),XK(20,12),TCP(20,12),NPM(12)
     2      , CPX(20,12),GAPX(12),FTEST(12),BTEST(12),H(12),XKB(10,12)
     3      , CPB(10,12),DXB(12)
      COMMON /TEMPS/ TEMOI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
     1      , TUL2(50),TY(200),TEMPI,TXO,SURTEM
      COMMON /ABLATS/ XMOG(50),TABL,TCHAR,RHOV,RHOC,TREC,XLOST,SOOTOS
     1      , SOOT,XMOC,XMT
      COMMON /INOIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      COMMON /HSPARA/ OX,     TL,VL,BL,OMP,VPT
      COMMON /FIXPRO/ CHARK,CHARC,ABLK,ABLC
      COMMON /FIXERS/ I1,I2,I3,I4,I5,I6
      COMMON /JUNK/ ERR1,ERR2,ERR3,ERR4
      COMMON /ARRH/ THETA(50),AP,XB,SN,CA
      COMMON/TABS/ TNOOE(50),OCHAR(50),ITABLE(9,10),ITAB(9,6)
     1            , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2            , IVIRG1,IVIRG2,TREAO,IERROR,ITABNO,AINPUT(9),W(50)
     3            , ISTART,IENO,ANSWR(350)
      EQUIVALENCE (ANSWR(1),CP(1)),(ANSWR(51),YK(1)),(ANSWR(201),CPGAS(1
     1)),(ANSWR(251),HV(1)),(ANSWR(301),HSUB)
      OO 10 I=1,NP
      IF(THETA(I).GT.0.01) GO TO 12
   10 CONTINUE
      IREAC1=NP+1
      IVIRG1=NP+1
      ICHAR2=NP
      GO TO 20
   12 ICHAR2=I-1
      IREAC1=I
      OO 15 I=IREAC1,NP
      IF(THETA(I).GT.0.995) GO TO 17
   15 CONTINUE
      IVIRG1=NP+1
      GO TO 20
   17 IREAC2=I-1
      IVIRG1=I
   20 I=0
   22 I=ITABLE(I+1,5)
   24 GO TO (30,40,50,50,70,70,90,100,110,190),I
   30 ISTART=IREAC1
      IEND=IREAC2
      IF(AINPUT(1))31,32,34
   31 CALL TBKINO(1)
C     ***********
      GO TO 22
   32 ITABLE(3,9)=100
      CALL TBKINO(3)
C     ***********
      ITABLE(5,9)=150
```

```
      CALL TBKINO(5)
C     ***********
      ITABLE(3,9)=50
      ITABLE(5,9)=50
      DO 33 K=IREAC1,IREAC2
   33 YK(K)=ANSWR(K+100)+(ANSWR(K+150)-ANSWR(K+100))*THETA(K)
      GO TO 22
   34 DO 35 K=IREAC1,IREAC2
   35 YK(K)=AINPUT(1)
      GO TO 22
   40 ISTART=IREAC1
      IEND=IREAC2
      IF(AINPUT(2))41,42,44
   41 CALL TBKINO(2)
C     ***********
      GO TO 22
   42 ITABLE(4,9)=100
      CALL TBKINO(4)
C     ***********
      ITABLE(6,9)=150
      CALL TBKINO(6)
C     ***********
      ITABLE(4,9)=0
      ITABLE(6,9)=0
      DO 43 K=IREAC1,IREAC2
   43 CP(K)=ANSWR(K+100)+(ANSWR(K+150)-ANSWR(K+100))*THETA(K)
      GO TO 22
   44 DO 45 K=IREAC1,IREAC2
   45 CP(K)=AINPUT(2)
      GO TO 22
   50 IF(ICHAR2.LT.1) GO TO 22
      IF(AINPUT(I).GT.0.) GO TO 56
      ISTART=ICHAR1
      IENO=ICHAR2
      IF(ICHAR3.LT.ICHAR2) GO TO 53
      ICHAR3=ICHAR2
      GO TO 55
   53 ICHAR3=ICHAR3+1
      OCHAR(ICHAR3)=TX2(ICHAR3)
   55 CALL TBKINO(I)
C     ***********
      GO TO 22
   56 IF(I.EQ.4) GO TO 58
      DO 57 K=ICHAR1,ICHAR2
   57 YK(K)=AINPUT(I)
      GO TO 22
   58 DO 59 K=ICHAR1,ICHAR2
   59 CP(K)=AINPUT(I)
      GO TO 22
   70 IF(AINPUT(I).GT.0.) GO TO 75
      ISTART=IVIRG1
      IENO=IVIRG2
      CALL TBKINO(I)
C     ***********
      GO TO 22
   75 IF(I.EQ.6) GO TO 78
      YK(IVIRG1)=AINPUT(I)
      GO TO 22
   78 CP(IVIRG1)=AINPUT(I)
      GO TO 22
```

```
   90 ISTART=ICHAR1
      IENO=IREAC2
      CALL TBKIND(I)
C     ***********
      GO TO 22
  100 ISTART=IREAC1
      IEND=IREAC2
      CALL TBKIND(I)
C     ***********
      GO TO 22
  110 ISTART=ICHAR1
      IEND=IREAC2
      CALL TBKIND(I)
C     ***********
      GO TO 22
  190 CONTINUE
C
C     OETERMINATION OF PROPER BACK-UP SHIELO MATERIAL PROPERTY
C
  199  OO 300 I=1,NMB
      OXB(I)=XBM(I)/((XNPM(I)-1.0)*12.0)
      LKP=NKPB(I)
      LCP=NCPB(I)
      NN=NPM(I)
      OO 280 J=1,NN
  200 IF(I5-1) 203,203,201
  201 IF(I5-LKP) 202,202,203
  202 IF(TX2T(J,I)-TXK(I5,I)) 206,220,205
  203 WRITE(20,204) I,TX2T(J,I)
  204 FORMAT(1HO,32H THE RANGE OF ONE OF THE NUMBER ,I2,71H BACKUP STRUC
     1TURE PROPERTY CURVE FITS WAS EXCEEOEO AT A TEMPERATURE OF ,1PE12.5
     2)
      ERR2=1.0
      GO TO 355
  205 I5=I5+1
      GO TO 201
  206 IF(TX2T(J,I)-TXK(I5-1,I)) 210,220,215
  210 I5=I5-1
      GO TO 200
  215 XKB(J,I)=XK(I5-1,I)+((XK(I5,I)-XK(I5-1,I))/(TXK(I5,I)-TXK(I5-1,I))
     1)*(TX2T(J,I)-TXK(I5-1,I))
      GO TO 230
  220 XKB(J,I)=XK(I5,I)
  230 IF(I6-1) 203,203,231
  231 IF(I6-LCP) 232,232,203
  232 IF(TX2T(J,I)-TCP(I6,I)) 234,245,233
  233 I6=I6+1
      GO TO 231
  234 IF(TX2T(J,I)-TCP(I6-1,I)) 235,245,240
  235 I6=I6-1
      GO TO 230
  240 CPB(J,I)=CPX(I6-1,I)+((CPX(I6,I)-CPX(I6-1,I))/(TCP(I6,I)-TCP(I6-1,
     1I)))*(TX2T(J,I)-TCP(I6-1,I))
      GO TO 280
  245 CPB(J,I)=CPX(I6,I)
  280 CONTINUE
      I5=2
      I6=2
  300 CONTINUE
  310 IF(OMP) 355,355,320
```

```
320 WRITE(20,330)
330 FORMAT(/1X,32H PROPERTIES OF ABLATION MATERIAL/)
    WRITE(20,335)
335 FORMAT(/5X,5HYK(I),9X,5HCP(I),9X,6HRHO(I)/)
    WRITE(20,340) (YK(I),CP(I),RHO(I),I=1,NP)
    IF(OMP.GT.0.0) GO TO 355
340 FORMAT(2X,1PE12.5,2X,1PE12.5,2X,1PE12.5)
    WRITE(20,345)
345 FORMAT(//1X,32H PROPERTIES OF BACK-UP STRUCTURE/)
    WRITE(20,347)
347 FORMAT(/5X,8HXKB(J,I),7X,8HCPB(J,I),7X,8HRHOBX(I),7X,7HEMFB(I),8X,
   17HEMBB(I),9X,6HOXB(I)/)
    DO 350 I=1,NMB
    KL=NPM(I)
    DO 349 J=1,KL
    WRITE(20,348) XKB(J,I),CPB(J,I),RHOBX(I),EMFB(I),EMBB(I),OXB(I)
348 FORMAT(3X,1PE12.5,3X,1PE12.5,3X,1PE12.5,3X,1PE12.5,3X,1PE12.5,3X,1
   1PE12.5)
349 CONTINUE
350 CONTINUE
355 RETURN
    END
```

```
C
C      THIS SUBROUTINE DETERMINES THE FRONT FACE LOCATION AND CHAR MASS
C      REMOVAL RATE
C
       SUBROUTINE RECESS(XMOC,XLOST,TREC,DT,RHOC,TS,SR,TX2,NREC,NRS,ERR5,
      1SXO,SOOT,OMP,SPRINT,RHOS,QDOT,QELH)
C
       DIMENSION TS(50),SR(50)
       IF(TX2-TREC) 10,20,20
   10  XMOC=0.0
       XLOST=0.0
       SOOT=0.0
       SPRINT=0.
       GO TO 60
   20  IF(NRS-1)25,25,21
   21  IF(NRS-NREC) 22,22,25
   22  IF(TX2-TS(NRS)) 32,40,30
   25  WRITE(20,26) TX2
   26  FORMAT(1HO,75H THE RANGE OF THE SURFACE RECESSION TABLE WAS EXCEED
      1ED AT A TEMPERATURE OF ,1PE12.5)
       ERR5=1.0
       GO TO 60
   30  NRS=NRS+1
       GO TO 21
   32  IF(TX2-TS(NRS-1)) 34,40,36
   34  NRS=NRS-1
       GO TO 20
   36  SX=SR(NRS-1)+((SR(NRS)-SR(NRS-1))/(TS(NRS)-TS(NRS-1)))
      1*(TX2-TS(NRS-1))
       GO TO 50
   40  SX=SR(NRS)
   50  XMYY=300.*SX*RHOC
       XMOO=.75*.23*3600.*QDOT/QELH
       IF(XMYY.LE.XMOO) GO TO 80
       SPRINT=2.
       XMOC=XMOO
       SX=XMOO/(RHOS*300.)
       XLOST=300.*SX*DT
       SOOT=SX*300.
       GO TO 51
   80  SPRINT=1.
       XMOC=XMYY
       XLOST=300.*SX*DT
       SOOT=SX*300.
   51  IF(OMP)60,60,52
   52  WRITE(20,54) SX,XLOST,XMOC
   54  FORMAT(1HO,3HSX=,1PE12.5,3X,6HXLOST=,1PE12.5,3X,5HXMOC=,1PE12.5)
   60  RETURN
       END
```

```
SUBROUTINE RESET
RETURN
END
```

```
      SUBROUTINE RITE(X,Y,NTBL,IBFN)
      OIMENSION X(1),Y(1),A(30)
      IFLG=0
      IBGN=IBFN
      WRITE(20,900)
  900 FORMAT(/3X86HTEMPERATURES AT SELECTEO THERMOCOUPLE LOCATIONS   DEP
     1TH - (IN),  TEMPERATURE - (OEG-F))
      NP=NTBL-IBGN+1
      IF(NP.LE.5)GO TO 500
      IF(NP.LE.10)GO TO 1000
C     SECTION 3
      IX=5
      IF(NP.LE.13) IX=4
      IF(NP.EO.13) IFLG=1
      IENO=IX+IBGN-1
      IF(IFLG.EO.1) IENO=IENO+1
      L=1
      ICT=0
   50 00 100 I=IBGN,IENO
      A(L)=X(I)
      A(L+1)=Y(I)
  100 L=L+6
      N=2*NP
      IF(ICT.NE.0)GO TO 101
      L= 3
      IBGN=IENO+1
      IENO=IENO+4
      ICT=1
      GO TO 50
  101 IF(ICT.NE.1)GO TO 102
      L=5
      IBGN=IEND+1
      IENO=NTBL
      ICT=2
      GO TO 50
  102 WRITE(20,150)
  150 FORMAT(/,7X,5HOEPTH,10X,11HTEMPERATURE,10X,5HOEPTH,10X,
     111HTEMPERATURE,10X,5HOEPTH,10X,11HTEMPERATURE)
      WRITE(20,151)(A(I),I=1,N)
  151  FORMAT(1X,E16.8,5(2X,E16.8))
      RETURN
C     SECTION 1
  500 WRITE(20,200)
  200  FORMAT(/,33X,5HOEPTH,27X,11HTEMPERATURE)
      WRITE(20,201)(X(I),Y(I),I=IBGN,NTBL)
  201  FORMAT(27X,E16.8,20X,E16.8)
      RETURN
C     SECTION 2
 1000 IX=5
      IF(NP.EO.6)IX=3
      IF((NP.EO.7).OR.(NP.EO.8))IX=4
      ICT=0
      L=1
      IENO=IX+IBGN-1
  290 00 300 I=IBGN,IENO
```

```
      A(L)=X(I)
      A(L+1)=Y(I)
  300 L=L+4
      IF(ICT.NE.0)GO TO 301
      ICT=1
      L=3
      IBGN=IEND+1
      IEND=NTBL
      GO TO 290
  301 N=NP*2
      WRITE(20,350)
  350 FORMAT(/10X5HDEPTH,18X11HTEMPERATURE,28X5HDEPTH,18X11HTEMPERATURE)
      WRITE(20,351)(A(I),I=1,N)
  351 FORMAT(5X,E16.8,10X,E16.8,20X,E16.8,10X,E16.8)
      RETURN
      END
```

```
C
C     SUBROUTINE SINGLE INTERPOLATES A=F(X)
C
      SUBROUTINE SINGLE(I,X)
      DIMENSION X(12)
      DIMENSION CP(50),YK(50),CPGAS(50),HV(50)
      COMMON/TABS/ TNODE(50),OCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IEND,ANSWR(350)
      EQUIVALENCE (ANSWR(1),CP(1)),(ANSWR(51),YK(1)),(ANSWR(201),CPGAS(1
     1)),(ANSWR(251),HV(1)),(ANSWR(301),HSUB)
      IS=ITABLE(I,9)+ISTART
      IE=ITABLE(I,9)+IEND
      I1=ISTART-1
      JX=ITABLE(I,2)
      DO 1000 K=IS,IE
      I1=I1+1
      IF(X(I1).GT.TABLES(JX)) GO TO 20
   15 JX=JX-1
      IF(X(I1).GT.TABLES(JX)) GO TO 100
      GO TO 15
   20 IF(X(I1).LT.TABLES(JX+1)) GO TO 100
      JX=JX+1
      GO TO 20
  100 KX=JX+ITABLE(I,7)
      ANSWR(K)=TABLES(KX)+(TABLES(KX+1)-TABLES(KX))*((X(I1)-TABLES(JX))
     */(TABLES(JX+1)-TABLES(JX)))
      IF(K.GT.IS) GO TO 1000
      ITABLE(I,2)=JX
 1000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SUBL(TW,PLPT,SDOTS,TS,SR,ALTX,NREC,SDOT,VELX,PL1,PL,PT2
     1,TSUBX,TSUBL)
C
      DIMENSION PES(10),TSUB(10),TS(10),SR(50)
C
      DATA(PES(I),I=1,10)/.001,.005,.01,.05,.1,.5,1.0,2.0,4.0,6.0/
      DATA(TSUB(I),I=1,10)/4640.,4900.,5050.,5340.,5460.,5740.,5880.,
     16000.,6130.,6200./
      NSUB=10
      IF(TW.LT.TSUBL) RETURN
      A=165000.0/TW
      IF(A.GT.88.) A=88.
      B=(0.612E+12)*EXP(-A)/(TW**0.324)
      SDOTS=B*3600.
C
C     SDOTS - FT/HR (SUBLIMATION RATE)
C     SDOT  - FT/HR (CHEMICAL ERROSION RATE)
C
      RETURN
      END
```

```
C      THIS SUBRDUTINE DETERMINES THE FORWARD TIME STEP TEMPERATURES
C      BY SDLVING THE TRI-DIAGDNAL MATRIX
       SUBROUTINE SWUFT(A,B,C,D,T,N,DMP)
       DIMENSIDN A(200),B(200),C(200),D(200),T(200),CP(200),DP(200)
       CP(1)=C(1)/B(1)
       DP(1)=D(1)/B(1)
       DD 100 I=2,N
       CP(I)=C(I)/(B(I)-A(I)*CP(I-1))
       DP(I)=(D(I)-A(I)*DP(I-1))/(B(I)-A(I)*CP(I-1))
  100  CDNTINUE
       T(N)=DP(N)
       NM1=N-1
       DO 200 J=1,NM1
       I=N-J
       T(I)=DP(I)-CP(I)*T(I+1)
  200  CONTINUE
       IF(DMP) 300,300,250
  250  WRITE(20,260)
  260  FDRMAT(//1X,43HCDEFFICIENTS CALCULATED BY SUBROUTINE SWUFT//)
       WRITE(20,270)
  270  FDRMAT( 6X,5HCP(I),10X, 5HDP(I),10X, 5H A(I), 12X,4HB(I),12X,4HC(I
      1),       12X,   4HD(I),12X, 4HT(I))
       WRITE(20,275)(CP(I),DP(I),A(I),B(I),C(I),D(I),T(I),I=1,N)
  275  FORMAT(7E16.8)
  300  RETURN
       END
```

```
      SUBROUTINE TBKIND (I)
      COMMON /ABPROP/ RHO(50)
      COMMON /TEMPS/ TEMOI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
      COMMON /FIXPRO/ CHARK,CHARC,ABLK,ABLC
      COMMON /ARRH/ THETA(50),AP,XB,SN,CA
      COMMON/TABS/ TNODE(50),DCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IEND,ANSWR(350)
      COMMON /PRES/ P(50),ALFAV,ALFAC,BETAV,BETAC,Z
      DIMENSION PATM(50)
C
   70 K=ITABLE(I,6)
      GO TO (150,82,87,90,93,96,99,102,105,108,110,120,130),K
C
C     TEMPERATURE DEPENDENT
C
   82 CALL SINGLE (I,TX2)
C     ***********
      GO TO 22
C
C     TEMPERATURE DEPENDENT --- IRREVERSIBLE
C
   87 DO 89 J1=ISTART,IEND
   89 TNODE(J1)=AMAX1(TNODE(J1),TX2(J1))
      CALL SINGLE(I,TNODE)
C     ***********
      GO TO 22
C
C     DENSITY DEPENDENT
C
   90 CALL SINGLE (I,RHO)
C     ***********
      GO TO 22
C
C     PRESSURE DEPENDENT
C
   93 DO 94 J1=1,50
   94 PATM(J1)=P(J1)/14.6959
      CALL SINGLE(I,PATM)
C     ***********
      GO TO 22
C
C     TEMPERATURE AND CHAR TEMPERATURE DEPENDENT
C
   96 CALL DDUBLE (I,TX2,DCHAR)
C     ***********
      GO TO 22
C
C     TEMPERATURE AND CHAR TEMPERATURE DEPENDENT --- IRREVERSIBLE
C
   99 DO 101 J1=ISTART,IEND
  101 TNODE(J1)=AMAX1(TNODE(J1),TX2(J1))
      CALL DDUBLE (I,TNODE,DCHAR)
C     ***********
```

```
      GO TO 22
C
C     TEMPERATURE AND DENSITY DEPENDENT
C
  102 CALL DDUBLE (I,TX2,RHD)
C     ***********
      GO TO 22
C
C     TEMPERATURE AND MAXIMUM TEMPERATURE DEPENDENT
C
  105 DO 106 J1=ISTART,IEND
  106 TNDDE(J1)=AMAX1(TNDDE(J1),TX2(J1))
      CALL DDUBLE (I,TX2,TNDDE)
C     ***********
      GO TO 22
C
C     TEMPERATURE(NR) AND MAXIMUM TEMPERATURE DEPENDENT
C
  108 DO 109 J1=ISTART,IEND
  109 TNDDE(J1)=AMAX1(TNDDE(J1),TX2(J1))
      CALL DDUBLE (I,TNDDE,TNDDE)
C     ***********
      GO TO 22
C
C     TEMPERATURE AND PRESSURE DEPENDENT
C
  110 DO 111 J1=1,50
  111 PATM(J1)=P(J1)/14.6959
      CALL DDUBLE(I,TX2,PATM)
C     ***********
      GO TO 22
  120 IS=ITABLE(I,9)+ISTART
      IE=ITABLE(I,9)+IEND
      DO 122 J1=IS,IE
  122 ANSWR(J1)=AINPUT(I)
      GO TO 22
  130 IS=ITABLE(I,9)+ISTART
      IE=ITABLE(I,9)+IEND
      J2=ISTART-1
      IF(I.GT.1) GO TO 134
      DO 132 J1=IS,IE
      J2=J2+1
  132 ANSWR(J1)=CHARK+(ABLK-CHARK)*THETA(J2)
      GO TO 22
  134 DO 136 J1=IS,IE
      J2=J2+1
  136 ANSWR(J1)=CHARC+(ABLC-CHARC)*THETA(J2)
      GO TO 22
  150 WRITE(20,103)
  103 FORMAT(1H1//,43HTABLE INTERPOLATION OPTION 1 IS NOT ALLOWED)
      IERROR=1
   22 RETURN
      END
```

```
C
C     SUBROUTINE TBLSET SETS UP THE INFORMATION FOR THE ARRAY ITABLE.
C
      SUBROUTINE TBLSET
      COMMON/TABS/ TNODE(50),OCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IEND,ANSWR(350)
      DO 500 I=1,9
      IF(ITABLE(I,1).LT.1) GO TO 500
      IF(ITABNO.LT.1) GO TO 55
      DO 50 J=1,ITABNO
      IF(ITAB(J,1).EQ.ITABLE(I,1)) GO TO 60
   50 CONTINUE
   55 ITABLE(I,1)=-ITABLE(I,1)
      IERROR=1
      GO TO 500
   60 K=ITAB(J,6)
      GO TO (100,100,100,100,100,200,200,200,200,200,200), K
  100 ITABLE(I,2)=ITAB(J,2)+1
      ITABLE(I,3)=0
      ITABLE(I,4)=ITAB(J,2)
      ITABLE(I,6)=ITAB(J,6)
      ITABLE(I,7)=ITAB(J,4)+2
      ITABLE(I,8)=ITAB(J,5)+3
      GO TO 500
  200 ITABLE(I,2)=ITAB(J,2)+ITAB(J,5)+3
      ITABLE(I,3)=ITAB(J,2)+1
      ITABLE(I,4)=ITAB(J,2)
      ITABLE(I,6)=ITAB(J,6)
      ITABLE(I,7)=ITAB(J,4)+2
      ITABLE(I,8)=ITAB(J,5)+3
  500 CONTINUE
      DO 550 I=1,2
      IF(AINPUT(I).EQ.-1.) ITABLE(I,6)=13
  550 CONTINUE
      DO 600 I=3,6
      IF(ITABLE(I,1).GT.0.) GO TO 600
      ITABLE(I,6)=12
  600 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TBLST(I)
C
      COMMON /INDIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      COMMON/TABS/ TNODE(50),DCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IEND,ANSWR(350)
C
      IF(I.GT.1) GO TO 200
      TREAD=0.
      ITABLE(1,9)=50
      ITABLE(2,9)=0
      ITABLE(3,9)=50
      ITABLE(4,9)=0
      ITABLE(5,9)=50
      ITABLE(6,9)=0
      ITABLE(7,9)=200
      ITABLE(8,9)=250
      ITABLE(9,9)=300
      ITABLE(1,10)=99
      ITABLE(2,10)=49
      ITABLE(3,10)=99
      ITABLE(4,10)=49
      ITABLE(5,10)=99
      ITABLE(6,10)=49
      ITABLE(7,10)=249
      ITABLE(8,10)=299
      ITABLE(9,10)=349
      RETURN
C
 200  IERROR=0
      CALL TBSHUV
C     ***********
C     CALL TBLRED
      CALL TBLSET
C     ***********
      CALL TBLWRT
C     ***********
      ICHAR1=1
      ICHAR2=0
      ICHAR3=0
      IREAC2=0
      IVIRG1=1
      IVIRG2=NP
      DO 300 I=1,50
      TNODE(I)=0.
 300  DCHAR(I)=0.
      RETURN
      END
```

```
C
C     SUBROUTINE TBSHUV IS CALLED AFTER READING DATA ITEMS BUT PRIOR TO
C     READING ANY TABLE DATA. ITS FUNCTION IS TO DROP UNNECESSARY TABLES
C     FROM STORAGE AND TO DETERMINE WHICH VARIABLES ARE TO BE TABLE
C     FUNCTIONS.
C
      SUBROUTINE TBSHUV
      DIMENSION IDUM(25)
      DIMENSION CP(50),YK(50),CPGAS(50),HV(50)
      COMMON/TABS/ TNODE(50),DCHAR(50),ITABLE(9,10),ITAB(9,6)
     1           , TABLES(500),ICHAR1,ICHAR2,ICHAR3,IREAC1,IREAC2
     2           , IVIRG1,IVIRG2,TREAD,IERROR,ITABNO,AINPUT(9),W(50)
     3           , ISTART,IEND,ANSWR(350)
      EQUIVALENCE (ANSWR(1),CP(1)),(ANSWR(51),YK(1)),(ANSWR(201),CPGAS(1
     1)),(ANSWR(251),HV(1)),(ANSWR(301),HSUB)
      N=9
      ITABLE(1,5)=N+1
      J=1
      INO=0
      DO 50 I=1,N
      IF(AINPUT(I).GT.-1000.) GO TO 20
      ITABLE(I,1)=-AINPUT(I)
      ITABLE(J,5)=I
      ITABLE(I+1,5)=N+1
      J=I+1
      INO=INO+1
      IDUM(INO)=-AINPUT(I)
      GO TO 50
   20 IF(I.GT.6) GO TO 22
      ITABLE(J,5)=I
      ITABLE(I+1,5)=N+1
      J=I+1
   22 J1=ITABLE(I,9)
      J2=ITABLE(I,10)
      DO 25 K=J1,J2
   25 ANSWR(K)=AINPUT(I)
      ITABLE(I,1)=0
   50 CONTINUE
      IF(INO.EQ.0 .OR. ITABNO.EQ.0) GO TO 250
      J=ITABNO
      DO 200 K=1,J
      DO 100 I=1,INO
      IF (ITAB(K,1).EQ.IDUM(I)) GO TO 200
  100 CONTINUE
      IF(K.EQ.J) GO TO 160
      JLOC=ITAB(K,2)-1
      J1=ITAB(K+1,2)
      J2=ITAB(J,3)
      DO 120 J3=J1,J2
      JLOC=JLOC+1
  120 TABLES(JLOC)=TABLES(J3)
      JNO=ITAB(K,3)-ITAB(K,2)+1
      J2=K+1
      DO 150 J1=J2,J
      ITAB(J1-1,1)=ITAB(J1,1)
      ITAB(J1-1,2)=ITAB(J1,2)-JNO
      ITAB(J1-1,3)=ITAB(J1,3)-JNO
      ITAB(J1-1,4)=ITAB(J1,4)
      ITAB(J1-1,5)=ITAB(J1,5)
  150 ITAB(J1-1,6)=ITAB(J1,6)
  160 ITABNO=ITABNO-1
  200 CONTINUE
      GO TO 300
  250 ITABNO=0
  300 RETURN
      END
```

```
C     THIS SUBROUTINE DETERMINES THE INITIAL TEMPERATURE DISTRIBUTION
C     IN THE HEAT SHIELD STRUCTURE
      SUBROUTINE TEMPD
C
      COMMON /BACKUP/ XNPM(12),RHDBX(12),XBM(12),EMBB(12),EMFB(12)
     1     , NKPB(12),NCPB(12),TXK(20,12),XK(20,12),TCP(20,12),NPM(12)
     2     , CPX(20,12),GAPX(12),FTEST(12),BTEST(12),H(12),XKB(10,12)
     3     , CPB(10,12),DXB(12)
      COMMON /TEMPS/ TEMDI(200),TX1(50),TX2(200),TX2T(10,12),TUL1(50)
     1     , TUL2(50),TY(200),TEMPI,TXO,SURTEM
      COMMON /INDIX/ NP,NP2,IFPT,NPBS,NPF,NMB
      COMMON /FNTBCK/ FBLDW,EMV,EMC,H300,TEST2,TENV,QIN,HENV,FENV
     1     , QLOSS,QHC,HXX(12),HX(50),TW(50)
      COMMON /HSPARA/ DX,    TL,VL,BL,OMP,VPT
      X=0.0
      IF(TEST2) 300,100,200
  100 DO 150 L=1,NPF
      TX1(L)=TEMPI
      TX2(L)=TEMPI
      TUL1(L)=TX1(L)
      TUL2(L)=TX2(L)
      TEMDI(L)=TEMPI
  150 CONTINUE
      DO 160 I=1,NMB
      JN=NPM(I)
      DO 155 M=1,JN
      TX2T(M,I)=TEMPI
  155 CONTINUE
  160 CONTINUE
      GO TO 320
  200 DO 220 L=1,NP
      TEMDI(L)=TXO+((TENV-TXO)/TL)**X
      TX1(L)=TEMDI(L)
      TX2(L)=TX1(L)
      TUL1(L)=TX1(L)
      TUL2(L)=TX1(L)
      X=X+DX
  220 CONTINUE
      L=NP+1
      DO 270 I=1,NMB
      KJ=NPM(I)
      DO 250 J=1,KJ
      TEMDI(L)=TXO+((TENV-TXO)/TL)**X
      TX1(L)=TEMDI(L)
      TX2(L)=TEMDI(L)
      TX2T(J,I)=TEMDI(L)
      X=X+DXB(I)
      L=L+1
  250 CONTINUE
      X=X+(GAPX(I)/12.0)
  270 CONTINUE
      GO TO 320
C     AN ARBRITARY TEMPERATURE DISTRIBUTION CAN BE READ IN FROM INPUT
C      DATA IF TEST2 IS A NEGATIVE NUMBER
  300 WRITE(20,310)
  310 FORMAT(1HO,79H THE VALUE OF TEST2 WAS NEGATIVE, SUBROUTINE TEMPD S
     1HOULD NOT HAVE BEEN CALLED.)
      ERR1=1.0
  320 RETURN
      END
```

```
C***
C*** SOR IS NOT USED
C*** HORT IS THE VARIABLE BEING TESTED
C*** I74 IS THE INOEX FLAG
C*** IREG IS THE ERROR FLAG
C***
       SUBROUTINE TESTH(SOR,HORT,I74,IREG)
       OIMENSION RANGE(10)
       OATA (RANGE(J),J=1,10)/5.,10.,15.,28.,80.,150.,400.,700.,1000.,
      1 2000./
       IF(HORT-1.)120,64,64
   64  IF(HORT-2000.)70,70,120
C
C      HORT IS GREATER THAN OR EQUAL TO 1., BUT LESS THAN OR EQUAL TO 20
C
   70  I74=3
       00 113 K=1,10
       IF(HORT-RANGE(K))115,115,107
  107  I74=I74+19
  113  CONTINUE
  115  IREG=2
       GO TO 123
  120  IREG=1
  123  RETURN
       ENO
```

```
===  OUTPUT FROM XPRTUTIL FOR RAS1810  ===

AT 08:18:48 ON 03/15/83 - RAS1810.STABII.FORT(TURF)

      SUBROUTINE TURF(QCON,VEL,ALT,NTRAPT,QCONC,RTR,OMP,SHAPEF,ITHIN,
     1                TIN,TOUT,NTURBT,TIME)
C
      COMMON /TRBATS/ PLA(300),TLA(300),HLA(300),VLA(300),TTA(300)
      COMMON /FACTRS/ AOT(300),FC(300),FR(300),FPLPT(300),SOVR1,PHI,
     1                FWX(300),WX1,WX2
      COMMON/TURBWT/ RENOLA(300),QTOLA(300)
      DIMENSION QCON(300),VEL(300),ALT(300),QCONC(300),T(25),V(25),
     1          ANSW(16),TIN(10),TOUT(10)
C
      DATA(T(I),I=1,21)/100.,900.,1800.,2700.,3600.,4500.,5400.,6300.,
     17200.,8100.,9000.,9900.,10800.,11700.,12600.,13500.,14400.,15300.,
     216200.,17100.,18000./
      DATA(V(I),I=1,21)/7.63E-8,55.8E-8,86.8E-8,110.8E-8,129.3E-8,146.
     111E-8,161.2E-8,175.1E-8,187.9E-8,199.9E-8,211.E-8,222.E-8,232.E-8,
     2242.E-8,252.E-8,261.E-8,269.E-8,278.E-8,286.E-8,294.E-8,302.E-8/
C
      IK=0
      IBC=1
      DO 650 I=1,NTRAPT
      RENOL=0.
      QTOVOL=1.0
      ZMAX=500000.
      ALTE=ALT(I)
      CALL ATMOS(ITHIN,ALTE,ZMAX,ANSW)
C     **********
      PAMB=ANSW(9)
      TAMB=ANSW(10)
      RHO=ANSW(11)*ANSW(13)/ANSW(5)
      MW=ANSW(15)
      VISC=ANSW(16)
      CALL FINOS(VEL(I)**2/847500.,1./ANSW(2),ANSW(1),ANSW(3),
     1           .24*TAMB/33.86,PT2P,HT2RT,R2,V1,SOVR,IREG)
C     **********
      HT2=HT2RT*33.86
      PT2=PT2P
      PL=FPLPT(I)*PT2
      IF(PL.LT..001) PL=.001
      PLP=ALOG10(PL)
      CALL MOLH(PLP,SOVR,HLRT,IREG1)
C     *********
      HL=HLRT*33.86
      CALL ALLMOL(SOVR,HLRT,ANS1,ANS2,ANS3,ANS4,IREG)
C     ***********
      RHOL=(10.**ANS2)*.002498
      TL=1.8*ANS3
      VL=0.
      IF(HT2.LT.HL) GO TO 70
      VL=224.*(SQRT(HT2-HL))
 70   PLA(I)=PL
      TLA(I)=TL
      HLA(I)=HL
      VLA(I)=VL
      TTA(I)=TAMB*(1.+.2*(VEL(I)/ANSW(12))**2)
      IF(NTURBT.EQ.0) GO TO 650
```

```
      IF(ALT(I).GE.ZMAX.OR.VEL(I).LT.2000.) GO TO 830
      IF(HT2.LT.HL) GO TO 830
      CALL DISCOT(TL,TL,T,V,V,-20,21,0,RMUL)
C     **********
      RENOL=VL*FWX(I)*(RHOL/RMUL)
      IF(RENOL.LT.RTR.OR.RENOL.GT.3.E6) GO TO 830
   81 QTOVOL=SHAPEF*RENOL**0.30103
      IF(IK.EQ.1) GO TO 83
      IF(IBC.LE.10) GO TO 82
      WRITE(20,820)
  820 FORMAT(98H1 MORE THAN 10 TURBULENT TRAJECTORY ZONES. IF MORE ZONES
     1 ARE NEEDED, DIMENSION TIN AND TOUT HIGHER)
      STOP
   82 TIN(IBC)=TIME(I)
      IK=1
      GO TO 83
  830 IF(IK.NE.1) GO TO 83
      TOUT(IBC)=TIME(I)
      IBC=IBC+1
      IK=0
   83 QCON(I)=QCONC(I)*QTOVOL
      RENOLA(I)=RENOL
      QTOLA(I)=QTOVOL
  650 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE UINTRP(X,XTBL,Y,YTBL,N,J)
      DIMENSION XTBL(50),YTBL(50)
      I=J
      IF(I.GT.N.OR.I.LT.2) I=2
   10 IF(XTBL(I-1).LE.X.AND.X.LE.XTBL(I)) GO TO 40
      IF(X.GT.XTBL(I)) GO TO 30
   20 I=I-1
      IF(I.GE.2) GO TO 10
      I=2
      GO TO 40
   30 I=I+1
      IF(I.LE.N) GO TO 10
      I=N
   40 FRACT=(X-XTBL(I-1))/(XTBL(I)-XTBL(I-1))
      Y=YTBL(I-1)+(YTBL(I)-YTBL(I-1))*FRACT
      RETURN
      END
```

```
      SUBROUTINE UNS (IC,IA,IDX,IDZ,IMS)
      IF (IC)   5,5,10
    5 IMS=1
      NC=-IC
      GOTO 15
   10 IMS=0
      NC=IC
   15 IF (NC-100)   20,25,25
   20 IA=0
      GOTO 30
   25 IA=1
      NC=NC-100
   30 IDX=NC/10
      IDZ=NC-IDX*10
      RETURN
      END
```

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